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DEVELOPMENT OF AN AIRCRAFT MANEUVER
LOAD SPECTRUM BASED ON VGH DATA

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JULY 1980

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ASD-TR-80-5037	2. GOVT ACCESSION NO. <i>DD-A102750</i>	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Development of an Aircraft Maneuver Load Spectrum Based on VGH Data,	5. TYPE OF REPORT & PERIOD COVERED Final Report.	
7. AUTHOR(s) John W. Lincoln	6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Aeronautical Systems Division (ASD/ENFS) Wright-Patterson AFB OH 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS Aeronautical Systems Division (ASD/ENFS) Wright-Patterson AFB OH 45433	12. REPORT DATE July 1980	
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	13. NUMBER OF PAGES 82	
	15. SECURITY CLASS. (of this report) Unclassified	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) Approval for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Velocity Probability Load factor Stress exceedance Altitude Test spectrum Histogram		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes a procedure whereby a full scale aircraft maneuver load fatigue spectrum can be developed from recorded VGH data. It is assumed in this development that the internal loads (stresses) at the appropriate control points are available for combinations of velocity, load factor, altitudes and weight so that an interpolation on these points will provide the desired accuracy. The procedure will generate (for a control point) the cumulative probability of exceeding a given stress, exceedances per hour of a given		

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stress level, the probability density function for stress and the stress spectrum. The aircraft spectrum is derived from the assumption that the aircraft test loads derived from a linear combination of balanced loading conditions will provide a good simulation of the stress history at and "between" the control points. The application of the program to new designs (mission analysis) and to tracking can be made without modification. The computer program for this calculation is included along with a sample problem. As an example of an application of this program, the stress exceedance functions for a control point on the wing of the F-4 are shown that were computed from the VGII data accumulated over a period of one year.

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FOREWARD

This report was prepared by John W. Lincoln, Structures Division of the Directorate of Flight Systems Engineering. The work was done as a research and development task to assist in the spectrum development work for the F-4 durability and damage tolerance assessment.

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LIST OF SYMBOLS

N_{v_i}	The number of indicated airspeed intervals in the VGH histogram
N_{n_z}	The number of normal load factor intervals in the VGH histogram
N_h	The number of altitude intervals in the VGH histogram
N_w	The number of weight intervals in the VGH histogram
v_i	Indicated airspeed for the VGH histogram intervals
n_{z_i}	Normal load factor for the VGH histogram intervals
h_i	Altitude for the VGH histogram intervals
w_i	Aircraft weight for the VGH histogram intervals
H_j	The VGH histogram
N_t	The total number of load occurrences in the VGH histogram
P_j	The joint probability density function derived from the VGH histogram
$N_{v_i}^R$	The number of intervals in a refinement of an indicated airspeed interval in the VGH histogram
$N_{n_z}^R$	The number of intervals in a refinement of a normal load factor interval in the VGH histogram
N_h^R	The number of intervals in a refinement of an altitude interval in the VGH histogram
N_w^R	The number of intervals in a refinement of a weight interval in the VGH histogram
V_i	A surface, the ordinates of which are indicated airspeeds for determining the stress at a control point
N_z	A surface, the ordinates of which are normal load factors for determining the stress at a control point

H	A surface, the ordinates of which are altitudes for determining the stress at a control point
W	A surface, the ordinates of which are weights for determining the stress at a control point
\hat{P}_J	The joint probability density function for the refined VGH histogram
N_p	The number of control points on the aircraft structure used in the derivation of the fatigue spectrum
P_{ψ}^a	The cumulative probability for the stress at the ath control point
$P_{D_{\psi}}^a$	The probability density function for the stress at the ath control point
A_{cb}^a	The stress for the ath load level at the bth point in the sky and the cth control point
r_c^a	The fatigue test stress for the ath load level and the cth control point
α^{ab}	Scaling coefficients for the ath load level and the bth point in the sky
ϕ^a	A surface (generated from the surface P_J) from which P_{ψ}^a can be determined for ath control point
ψ^a	The stress surface for the ath control point
S^a	A set of ordinates of the graph $1 - P_{\psi}^a$
$S^a(i)$	The ith member of S^a

SECTION I

INTRODUCTION

In the application of the mission analysis required by MIL-A-008866A (USAF) to fighter and attack aircraft a problem arises in the selection of the point in the sky (velocity, altitude, and weight) for the load factor spectrum for the combat segment of the mission. It can be shown that in many cases important differences in the spectrum can be obtained from two "reasonable" point selections.

The problem has been particularly severe on some existing aircraft in that a ten percent shift in the stress spectrum can produce a factor of two change in life. Therefore, when it is considered that essentially all of the fatigue damage for fighter and attack aircraft is done in the combat segment, this part of the mission deserves special attention.

From an examination of available VGH data, it is evident that in both the air-to-air and air-to-ground operations a fairly wide variation in velocity, altitude, and weight is observed. Therefore, it would be surprising if a single point in the sky would provide an accurate prediction of the stress spectrum for a control point. This is even more evident for those aircraft which experience non-linearities in the aerodynamic data (i.e., tip stall).

One possible solution is to use multiple points in the sky for this calculation. This can be effectively accomplished by taking the points in the sky and their relative frequency of occurrence that are obtained from that portion of the fleet that is equipped with multichannel recorders (twenty percent of the fleet, which is consistent with current policy, is believed to be an adequate sample). This can be done by taking the VGH histogram (the relative frequency of airspeed, normal load factor, altitude, and weight) and dividing by the total number of load occurrences to obtain the probability that a load will occur in a given interval of airspeed, normal load factor, altitude, and weight. A stress level is selected and a summation is made for each such probability where the corresponding stress at the midpoint of the interval of airspeed, etc, is greater than the selected stress level. This computation produces the cumulative probability of exceeding a stress level. Since the intervals used for the data collection were not designed for this calculation, a provision is made to subdivide the intervals to improve the accuracy of the calculation. This technique is explained in Section III. From the cumulative

probability, the number of stress exceedances per hour, the probability density function, and the stress spectrum can be obtained.

Having the functions referred to above for a number of control points that is adequate to cover the aircraft structure (this number may have to be obtained by trial and error), one may generate the full scale aircraft spectrum by assuming that an arbitrary loading at the control points of the structure can be derived from a linear combination of the loading imposed by balanced load conditions. If N_p control points are used, then N_p balanced load conditions are used to represent the control point load. The use of "representative" balanced load conditions should provide a satisfactory interpolation between control points. These intermediate points should be spot checked against the true spectrum to see if the control point coverage is adequate.

Of course, for a new design, the VGH data does not exist and consequently direct application of this method is impossible. In some cases it will be possible to overcome this difficulty by taking existing VGH data from older aircraft and by use of judgement adapt it to this procedure. In any event, the method should be applied when the proper data becomes available so that by suitable tests and analysis the appropriate changes may be made in the aircraft life predictions.

One important application of this procedure is fighter/attack tracking. The unusual technique is to use the fleet counting accelerometer data and compute the stress for a single point in the sky that is believed to be representative of the particular mission flown (i.e., air-to-air or air-to-ground). In lieu of this approach, one could compute from the VGH data the conditional probability of exceeding a stress given the normal load factor. If this function were available, it would be possible to track to any desired probability on even multiple probability levels depending on what results are desired. This function can be generated from this program by setting all occurrences equal to zero except those that fall in the desired load factor interval. The high positive and low negative load factors may require an extrapolation from neighboring load factors because there may be too few data points to adequately describe these functions.

The program that is discussed in this report is based on the load occurrences in the VGH histogram being dependent on indicated airspeed, normal load factor, altitude, and weight. The stress function is based on the same quantities. An immediate alternate that is

included is to use equivalent load factor instead of load factor. This removes the weight dependency and considerably reduces the magnitude of the input. This option is included in the computer program described in the text. Other alternates that could be obtained by a simple modification of the program are listed as follows:

VGH data based on	Stress function based on
1. Indicated airspeed, normal load factor, altitude, and weight.	Mach no., normal load factor, altitude, and weight.
2. Mach no., normal load factor, altitude, and weight.	Mach no., normal load factor, altitude, and weight.
3. Equivalent airspeed, normal load factor, and weight	Equivalent airspeed, normal load factor, and weight.

The extension of this program to include other degrees of freedom for the aircraft is immediately evident. The major difficulty is the management of the input data required for the load occurrences and the stress function.

SECTION II

ANALYTICAL DERIVATION OF THE SPECTRUM

The first step in the derivation of the fatigue spectrum is to solve for the stress probability distribution function. This requires that the histogram of occurrences in intervals of indicated airspeed, load factor, altitude, and weight be defined. To do this suppose that each of N_{v_i} , N_{n_z} , N_h , and N_w is a positive integer and

- (1) v_{ij} is a simple graph such that the x-projection of v_{ij} is the set of integers in $[1, N_{v_i} + 1]$ and if i is an integer in $[1, N_{v_i} + 1]$ and $i + 1$ is in $[1, N_{v_i} + 1]$ then the indicated airspeed $v_{ij}(i)$ is less than the indicated airspeed $v_{ij}(i + 1)$
- (2) n_{z_j} is a simple graph such that the x-projection of n_{z_j} is the set of integers in $[1, N_{n_z} + 1]$ and if j is an integer in $[1, N_{n_z} + 1]$ and $j + 1$ is in $[1, N_{n_z} + 1]$ then the normal load factor $n_{z_j}(j)$, is less than the normal load factor $n_{z_j}(j + 1)$
- (3) h_i is a simple graph such that the x-projection of h_i is the set of integers in $[1, N_h + 1]$ and if k is an integer in $[1, N_h + 1]$ and $k + 1$ is in $[1, N_h + 1]$ then the altitude $h_i(k)$, is less than the altitude $h_i(k + 1)$
- (4) w_j is a simple graph such that the x-projection of w_j is the set of integers in $[1, N_w + 1]$ and if m is an integer in $[1, N_w + 1]$ and $m + 1$ is in $[1, N_w + 1]$ the weight $w_j(m)$, is less than the weight $w_j(m + 1)$

Further, suppose H_J is a simple surface such that

$[v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m), H_J(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))]$ is a point of H_J only if

- (1) i is in $[1, N_{v_i}]$, j is in $[1, N_{n_z}]$, k is in $[1, N_h]$,
 m is in $[1, N_w]$ and
- (2) $H_J(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))$ is the number of "load occurrences" in the rectangular interval
 $[v_{ii}(i), v_{ii}(i+1); n_{z_i}(j), n_{z_i}(j+1); h_i(k), h_i(k+1); w_i(m), w_i(m+1)]$
and these load occurrences are assumed to be uniformly distributed within the rectangular interval.

The surface H_J is called the VGH histogram for v_{ii} , n_{z_i} ,
 h_i , and w_i .

The total number of load occurrences included in the VGH histogram H_J is

$$N_t = \sum_{i=1}^{N_{v_i}} \sum_{j=1}^{N_{n_z}} \sum_{k=1}^{N_h} \sum_{m=1}^{N_w} H_J(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))$$

Therefore, by definition, the probability that the indicated airspeed, normal load factor, altitude, and weight is in the rectangular interval $[v_{ii}(i), v_{ii}(i+1); n_{z_i}(i), n_{z_i}(j+1); h_i(k), h_i(k+1); w_i(m), w_i(m+1)]$ is

$$P_J(i, j, k, m) = \frac{H_J(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))}{N_t}$$

Now suppose that if i is in $[1, N_{V_i} - 1]$ then the interval $[v_{ii}(i), v_{ii}(i + 1)]$ is covered by $N_{V_i}^R$ equal intervals, if j is in $[1, N_{n_z} - 1]$ then $[n_{z_i}(j), n_{z_i}(j + 1)]$ is covered by $N_{n_z}^R$ equal intervals, if k is in $[1, N_h - 1]$ then $[h_i(k), h_i(k + 1)]$ is covered by N_h^R equal intervals, and if m is in $[1, N_w - 1]$ then $[w_i(m), w_i(m + 1)]$ is covered by N_w^R equal intervals.

Since it was supposed that the load occurrences are within the rectangular interval $[v_{ii}(i), v_{ii}(i + 1); n_{z_i}(j), n_{z_i}(j + 1); h_i(k), h_i(k + 1); w_i(m), w_i(m + 1)]$ then the probability that the indicated airspeed, normal load factor, altitude, and weight is in the rectangular interval

$$\begin{aligned} & [v_{ii}(i), v_{ii}(i) + \frac{v_{ii}(i + 1) - v_{ii}(i)}{N_{V_i}^R}; \\ & n_{z_i}(j), n_{z_i}(j) + \frac{n_{z_i}(j + 1) - n_{z_i}(j)}{N_{n_z}^R}; \\ & h_i(k), h_i(k) + \frac{h_i(k + 1) - h_i(k)}{N_h^R}; \\ & w_i(m), w_i(m) + \frac{w_i(m + 1) - w_i(m)}{N_w^R}] \end{aligned}$$

is

$$\hat{P}_J(i, j, k, m) = \frac{H_J(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))}{N_t N_{V_i}^R N_{n_z}^R N_h^R N_w^R}$$

(1) Now suppose that V_i is a simple surface such that the x-y projection of V_i is the set of integers in the rectangular

interval $[1, N_{v_i} + 1; 1, N_{v_i}^R]$ and if i and $i + 1$ are integers

in $[1, N_{v_i} + 1]$ and i_R is an integer in $[1, N_{v_i}^R]$ then

$$v_i(i, i_R) = v_{ii}(i) + \left(\frac{i_R - 0.5}{N_{v_i}^R} \right) (v_{ii}(i + 1) - v_{ii}(i))$$

- (2) N_z is a simple surface such that the x - y projection of N_z is the set of integers in the rectangular interval $[1, N_{n_z} + 1; 1, N_{n_z}^R]$ and if j , and $j + 1$ are integers in

$[1, N_{n_z} + 1]$ and j_R is an integer in $[1, N_{n_z}^R]$ then

$$N_z(j, j_R) = n_{z_i}(j) + \left(\frac{j_R - 0.5}{N_{n_z}^R} \right) (n_{z_i}(j + 1) - n_{z_i}(j))$$

- (3) H is a simple surface such that the x , y projection of H is the set of integers in the rectangular interval $[1, N_h + 1; 1, N_h^R]$ and if k and $k + 1$ are integers in $[1, N_h + 1]$ and

k_R is an integer in $[1, N_h^R]$ then

$$H(k, k_R) = h_i(k) + \left(\frac{k_R - 0.5}{N_h^R} \right) (h_i(k + 1) - h_i(k))$$

- (4) W is a simple surface such that the x , y projection of W is the set of integers in the rectangular interval $[1, N_w + 1; 1, N_w^R]$ and if m and $m + 1$ are integers in $[1, N_w + 1]$

and m_R is an integer in $[1, N_w^R]$ then

$$W(m, m_R) = w_i(m) + \left(\frac{m_R - 0.5}{N_w^R} \right) (w_i(m + 1) - w_i(m))$$

The assumption is made that the stress at a point in the structure depends only on the indicated airspeed, normal load factor, altitude and weight. Therefore, if it is supposed that each of a and N_p is a positive integer such that a is in $[1, N_p]$

and ψ^a is a simple surface such that $(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R), \psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R))$ is a point of ψ^a only if i is in $[1, N_{V_i} + 1]$, i_R is in $[1, N_{V_i}^R]$, \dots, m is in $[1, N_w + 1]$, m_R is in $[1, N_w^R]$ and $\psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R))$ is the stress for the a th control point corresponding to the indicated airspeed $V_i(i, i_R)$, the normal load factor $N_z(j, j_R)$, the altitude $H(k, k_R)$, and the weight $W(m, m_R)$.

The surfaces ψ^a and \hat{P}_j are used in the calculation of the cumulative probability of exceeding a given stress as follows: Suppose that N_{Γ_L} is a positive integer and Γ_L is a uniformly increasing sequence with x -projection $[1, N_{\Gamma_L}]$ and ϕ^a is a simple surface such that

$$(1) \quad \phi^a(i, j, k, m, i_R, j_R, k_R, m_R) = \hat{P}_j(i, j, k, m) \\ \text{if } \psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R)) > \Gamma_L(b)$$

$$(2) \quad \phi^a(i, j, k, m, i_R, j_R, k_R, m_R) = 0 \\ \text{if } \psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R)) \leq \Gamma_L(b)$$

Therefore, the probability that the stress is greater than $\Gamma_L(b)$ is

$$P_{\psi^a}(\Gamma_L(b)) = \sum_{i=1}^{N_{V_i}} \sum_{j=1}^{N_{n_z}} \sum_{k=1}^{N_h} \sum_{m=1}^{N_w} \sum_{i_R=1}^{N_{V_i}^R} \sum_{j_R=1}^{N_{n_z}^R} \sum_{k_R=1}^{N_h^R} \sum_{m_R=1}^{N_w^R} \phi^a(i, j, k, m, i_R, j_R, k_R, m_R)$$

The probability density function $P_{D_{\psi^a}}$ is the derivative of the cumulative probability function P_{ψ^a} . This derivative is computed as follows: Suppose a is an integer in $[1, N_p]$ and that ζ^a is a simple graph with x -projection the interval $[1, N_{\Gamma_L}]$ such that

(1) if b is an integer in $[1, N_{\Gamma_L}]$ then $\zeta^a(b) = P_{D_\Psi}a(b)$ and

(2) if c is a number in $[b, b + 2]$ there exists a $u_1, u_2,$
and u_3 such that $\zeta^a(c) + u_1c^2 + u_2c + u_3$ where $u_1, u_2,$
 u_3 are determined from the equations

$$\begin{aligned}\zeta^a(b) &= b^2 & b & 1 & u_1 \\ \zeta^a(b+1) &= (b+1)^2 & (b+1) & 1 & u_2 \\ \zeta^a(b+2) &= (b+2)^2 & (b+2) & 1 & u_3\end{aligned}$$

Therefore

(1) if $b = 1$

$$P_{D_\Psi}a(1) = 2u_1 \Gamma_L(1) + u_2$$

$$P_{D_\Psi}a(2) = 2u_1 \Gamma_L(1) + u_2$$

(2) if b is in $[2, N_{\Gamma_L} - 3]$

$$P_{D_\Psi}a(b+1) = 2u_1 \Gamma_L(b+1) + u_2$$

(3) if $b = N_{\Gamma_L} - 2$

$$P_{D_\Psi}a(N_{\Gamma_L} - 1) = 2u_1 \Gamma_L(N_{\Gamma_L} - 1) + u_2$$

$$P_{D_\Psi}a(N_{\Gamma_L}) = 2u_1 \Gamma_L(N_{\Gamma_L}) + u_2$$

The next step in the derivation of the fatigue loading spectrum is to determine the stress and the frequency of that stress in the spectrum. This is done by an indirect process as shown below. Suppose that the fatigue test spectrum is to be composed of N cycles at M stress levels. Further, suppose that a is a positive integer in $[1, N_p]$ and S^a is a sequence of M numbers such that $s^a(i)$ and $s^a(j)$ are members of S^a only if $0 < s^a(i) < s^a(j) < 1$ and $i < j$.

Therefore, each member of S^a corresponds to an ordinate of the graph $1-P_\psi a$. The M abscissas corresponding to these M ordinates are defined as the M stress levels of the spectrum for the a th control point. The graph $1-P_\psi a$ is known at N_{Γ_L} points. Consequently, an approximation to $1-P_\psi a$ must be found in order to compute the spectrum stress levels. Suppose β is a simple graph with x -projection the interval $[\Gamma_L(1), \Gamma_L(N_{\Gamma_L})]$ and if k is in $[1, N_{\Gamma_L}]$ then $\beta(\Gamma_L(k)) = 1-P_\psi a(\Gamma_L(k))$. Further, suppose that if $i-1, i$, and $i+1$ are in $[1, N_{\Gamma_L}]$, δ_L is $\Gamma_L(k+1) - \Gamma_L(k)$, and x is in $[-\delta_L, \delta_L]$ then

$$\beta(x + \Gamma_L(k)) = [1 \frac{x}{\delta_L} (\frac{x}{\delta_L})^2] \begin{bmatrix} 0 & 1 & 0 \\ -\frac{1}{2} & 0 & \frac{1}{2} \\ \frac{1}{2} & -1 & \frac{1}{2} \end{bmatrix} \begin{bmatrix} \beta(\Gamma_L(k-1)) \\ \beta(\Gamma_L(k)) \\ \beta(\Gamma_L(k+1)) \end{bmatrix}$$

It follows then that if i is in $[1, M]$ there exists an integer k such that $P_\psi a(\Gamma_L(k-1)) \leq s^a(i) \leq P_\psi a(\Gamma_L(k))$ and a number x such that $\beta(x + \Gamma_L(k)) = s^a(i)$. The number x is obtained from a solution of a quadratic equation and $x + \Gamma_L(k)$ is the stress corresponding to $s^a(i)$.

The fraction of the N cycles, n_i , that are associated with the i th stress level is defined as follows:

$$n_1 = \frac{s(1) + s(2)}{2}$$

$$n_i = \frac{s(i+1) - s(i-1)}{2} \quad 1 < i < M$$

$$n_M = 1 - \frac{(s(M) + s(M-1))}{2}$$

It follows then that if i is in $[1, M]$ and if the sequence S^a is used for each of the control points then there will be an equal number of loading cycles for the i th load level for each of the control points.

The final step is to determine a set of coefficients which when multiplied by the stresses corresponding to balanced load conditions for the aircraft will produce the desired stress levels at the aircraft control points. Suppose a is a positive integer in $[1, M]$, b is a positive integer in $[1, N_p]$, and c is a positive integer in $[1, N_p]$. Therefore, if A_{cb}^a is the stress for the a th load level at the b th point in the sky and the c th control point and r_c^a is the stress desired in the fatigue test for the a th load level and the c th control point then there exists a set of coefficients α_{ab} such that $r_c^a = A_{cb}^a \alpha_{ab}$.

SECTION III

DESCRIPTION OF THE COMPUTER PROGRAM

1 NOTATION

The right hand side of the following relations are defined in Section II.

$$NT421 = N_{v_i}$$

$$NT422 = N_{n_z}$$

$$NT423 = N_h$$

$$NT424 = N_w$$

$$NT = N_t$$

$$PJT = \hat{P}_j$$

$$NRVI = N_{v_i}^R$$

$$NRNZ = N_{n_z}^R$$

$$NRH = N_h^R$$

$$NRW = N_w^R$$

$$VII = v_{ii}$$

$$NZI = n_{z_i}$$

$$HI = h_i$$

$$WI = w_i$$

$$VI = v_i$$

$$NZ = N_z$$

$$H = H$$

$$W = W$$

$$NPS = N_p$$

$$PPSI = P_\psi a \text{ (The } a \text{ is not explicitly identified in the program)}$$

$$PDPSI = P_{D_\psi} a \text{ (The } a \text{ is not explicitly identified in the program)}$$

$$PS = A$$

$PLD = \Gamma$
 $\text{ALPHA} = \alpha$
 $FVI = v_{ii}(N_{v_i} + 1)$
 $FNZ = n_{z_i}(N_{n_z} + 1)$
 $FH = h_i(N_h + 1)$
 $FW = w_i(N_w + 1)$
 $\text{FACTOR} - \text{Stress scaling factor. FACTOR} = 1 \text{ unless otherwise specified.}$
 $\text{HOURS} - \text{The number of hours of data in the VGH histogram}$
 $PSIL = \Gamma_L$
 $\text{AREAN} = s^a$
 $\text{DELTA} = \delta_L$
 $\text{APDPSI}(I) = 1.0 - PPSI(I)$
 $\text{PSILL}(I) - \text{The stress level that is the abscissa of the point of PPSI whose ordinate is AREAN}(I)$
 $\text{FRAC}(I) - \text{The fraction of the total number of cycles in the spectrum that correspond to PSILL}$
 $NPSIL = N_{\Gamma_L}$
 $NPSILL = M$
 $\text{EXCEED}(I) - \text{The number of exceedances per hour of the stress PSIL}(I)$
 $\text{NZERO} - \text{Control number to zero the input numbers at the start of a run and then prevent them from being zeroed between cases}$
 $\text{NPSCT} - \text{Control number for counting the number of control points for which a spectrum has been computed in a single run}$

2 INTERPOLATION PROCEDURE

Since the stress is initially calculated for only a finite set of points on the stress surface, an assumption must be made to determine the stress for a given indicated airspeed, normal load factor, altitude, and weight. Specifically, the problem may be expressed as follows: Given that NT421, NT422, NT423, NT424, NRV1, NRNZ, NRH, and NRW is a positive integer and I is in [1,NT421], J is in [1,NT422], K is in [1,NT423], M is in [1,NT424], IR is in [1,NRV1], JR is in [1,NRNZ], KR is in [1,NRH], MR is in [1,NRW] and a is in [1,N_p] it is required to create an approximation in the form

$\xi^a(I, J, K, M, IR, JR, KR, MR) =$

$\Xi^a(VI(I, IR), NZ(J, JR), H(K, KR), W(M, MR))$

for the stress as expressed by

$\psi^a(I, J, K, M, IR, JR, KR, MR) =$

$\Psi^a(VI(I, IR), NZ(J, JR), H(K, KR), W(M, MR))$

where Ξ^a is a ruled surface based on $2^4 = 16$ points of Ψ^a . The method of choosing these 16 points and the calculation of the stress approximation is described below.

The first step is to define the function TABLE which contains the projections and ordinates of the Ψ^a surface.

Suppose each of NTAB1, NTAB2, NTAB3, and NTAB4 is a positive integer and that

$$NN12 = NTAB1 + NTAB2$$

$$NN13 = NN12 + NTAB3$$

$$NN14 = NN13 + NTAB4$$

$$NP = NTAB1 \cdot NTAB2 \cdot NTAB3 \cdot NTAB4$$

$$NF = NN14 + NP$$

Further, suppose that TABLE is a simple graph such that the x-projection of TABLE is the set of integers in the interval [1, NF] and each of I1, I2, I3, and I4 is a positive integer.

Also,

- (1) if I1 and I1 + 1 are in [1, NTAB1] then the indicated airspeed TABLE (I1) is less than the indicated airspeed TABLE (I1 + 1)
- (2) if I2 and I2 + 1 are in [NTAB1 + 1, NN12] then the normal load factor TABLE (I2) is less than the normal load factor TABLE (I2 + 1)
- (3) if I3 and I3 + 1 are in [NN12 + 1, NN13] then the altitude TABLE (I3), is less than the altitude TABLE (I3 + 1)
- (4) if I4 and I4 + 1 are in [NN13 + 1, NN14] then the weight TABLE (I4) is less than the weight TABLE (I4 + 1)
- (5) if I1 is in [1, NTAB1], I2 is in [NTAB1 + 1, NN12], I3 is in [NN12 + 1, NN13], I4 is in [NN13 + 1, NN14]

and n is in $[NN14 + 1, NF]$ and is equal to $NN14 + (I4 - NN13 - 1) \cdot NTAB3 \cdot NTAB2 \cdot NTAB1 + (I3 - NN12 - 1) \cdot NTAB2 \cdot NTAB1 + (I2 - NTAB1 - 1) \cdot NTAB1 + I1$ then the stress TABLE (n) is the stress that corresponds to the indicated airspeed TABLE (I1), the normal load factor TABLE (I2), the altitude TABLE (I3) and the weight TABLE (I4).

The positive integers I1, I2, I3, and I4 are determined as follows: A search is made for the integer i that will determine the smallest number TABLE (i) that equals or exceeds $VI(I, IR)$. If $i = 1$ satisfies this requirement then I1 is set equal to 2. If i is in $[2, NTAB1]$ then I1 is set equal to i . If no i can be found in $[2, NTAB1]$ then I1 is set equal to $NTAB1$. A search is made for the integer j that will determine the smallest number TABLE (j) that equals or exceeds $(NZ(J, JR))$. If $j = NTAB1 + 1$ then I2 is set equal to $NTAB1 + 2$. If j is in $[NTAB1 + 2, NN12]$ then I2 is set equal to j . If no j can be found to satisfy the requirement then I2 is set equal to $NN12$. Also, a search is made for the integer k that will determine the smallest number TABLE (k) that equals or exceeds $H(K, KR)$. If $k = NN12 + 1$ then I3 is set equal to $NN12 + 2$. If k is in $[NN12 + 2, NN13]$ then I3 is set equal to k . If no k can be found in $[NN12 + 2, NN13]$ then I3 is set equal to $NN13$. A final search is made for the integer m that will determine the smallest number TABLE (m) that equals or exceeds $W(M, MR)$. If $m = NN13 + 1$ then I4 is set equal to $NN13 + 2$. If m is in $[NN13 + 2, NN14]$ then I4 is set equal to m . If no m can be in $[NN13 + 2, NN14]$ then I4 is set equal to $NN14$.

The next step is to identify the integers required for the final calculations.

With

$$\begin{aligned} NP12 &= NTAB1 \cdot NTAB2 \\ NP13 &= NP12 \cdot NTAB3 \end{aligned}$$

these are:

$$\begin{aligned} N2222 &= NN14 + (I4 - NN13 - 1) \cdot NP13 + (I3 - NN12 - 1) \cdot \\ &\quad NP12 + (I2 - NTAB1 - 1) \cdot NTAB1 + I1 \\ N1222 &= N22 - 1 \\ N2122 &= N222 - NTAB1 \\ N1122 &= N2122 - 1 \\ N2212 &= N2222 - NP12 \end{aligned}$$

$N1212 = N2212 - 1$
 $N2112 = N2212 - NTAB1$
 $N1112 = N2112 - 1$
 $N2221 = N222 - NP13$
 $N1221 = N2221 - 1$
 $N2121 = N2221 - NTAB1$
 $N1121 = N2121 - 1$
 $N2211 = N2221 - NP12$
 $N1211 = N2211 - 1$
 $N2111 = N2211 - NTAB1$
 $N1111 = N2111 - 1$

Therefore, if

$$X1RAT = \frac{VI(I, IR) - TABLE(I1-1)}{TABLE(I1) - TABLE(I1-1)}$$

$$X2RAT = \frac{NZ(J, JR) - TABLE(I2-1)}{TABLE(I2) - TABLE(I2-1)}$$

$$X3RAT = \frac{H(K, KR) - TABLE(I3-1)}{TABLE(I3) - TABLE(I3-1)}$$

$$X4RAT = \frac{W(M, MR) - TABLE(I4-1)}{TABLE(I4) - TABLE(I4-1)}$$

then

$$\begin{aligned} AMP111 &= TABLE(N1111) + X1RAT(TABLE(N2111) - TABLE(N1111)) \\ AMP211 &= TABLE(N1211) + X1RAT(TABLE(N2211) - TABLE(N1211)) \\ AMP121 &= TABLE(N1121) + X1RAT(TABLE(N2121) - TABLE(N1121)) \\ AMP221 &= TABLE(N1221) + X1RAT(TABLE(N2221) - TABLE(N1221)) \\ AMP112 &= TABLE(N1112) + X1RAT(TABLE(N2112) - TABLE(N1112)) \\ AMP212 &= TABLE(N1212) + X1RAT(TABLE(N2212) - TABLE(N1212)) \\ AMP122 &= TABLE(N1122) + X1RAT(TABLE(N2122) - TABLE(N1122)) \\ AMP222 &= TABLE(N1222) + X1RAT(TABLE(N2222) - TABLE(N1222)), \end{aligned}$$

$$AMP11 = AMP111 + X2RAT(AMP211 - AMP111)$$

$$AMP12 = AMP112 + X2RAT(AMP212 - AMP112)$$

$$AMP22 = AMP122 + X2RAT(AMP222 - AMP122),$$

$$\begin{aligned} AMP1 &= AMP11 + X3RAT(AMP21 - AMP11) \\ AMP2 &= AMP12 + X3RAT(AMP22 - AMP12), \end{aligned}$$

$$\xi^a (K, J, K, M, IR, JR, KR, MR) = (AMP1 + X4RAT(AMP2 - AMP1)) \cdot FACTOR$$

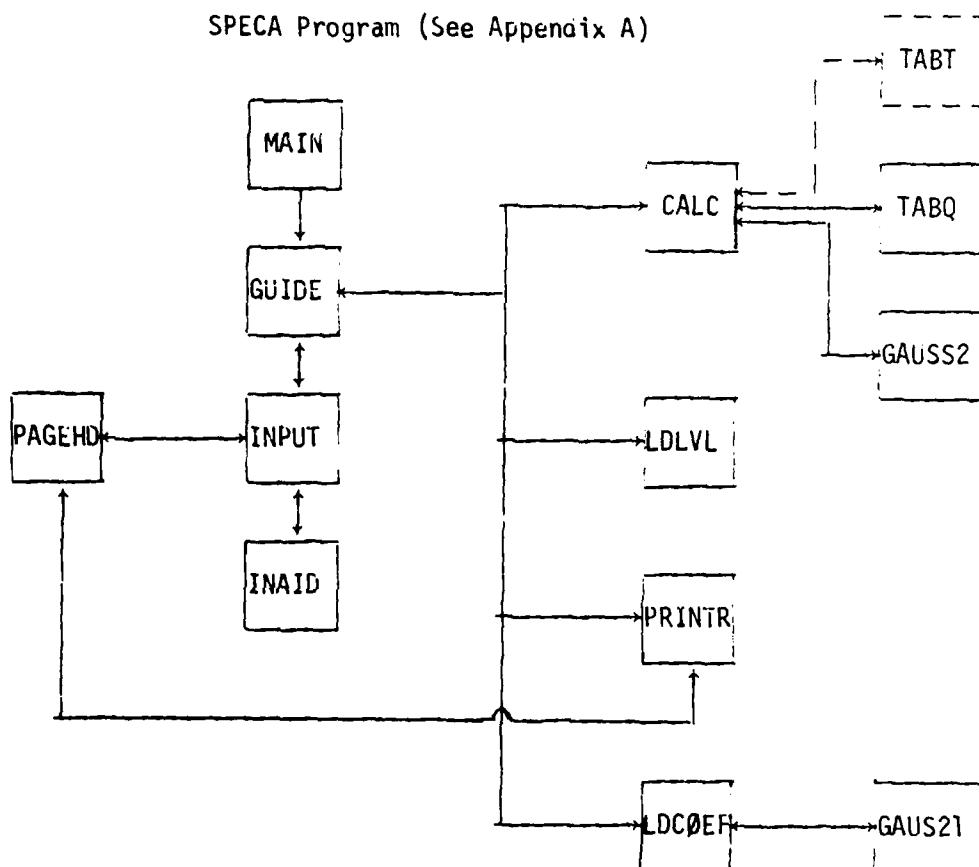
It is seen that the sixteen points on the ψ^a surface are reduced to eight points on the ξ^a surface by an interpolation on the indicated airspeed. The eight points are reduced to four points on the ξ^a surface by an interpolation on the normal load factor. Next, the

four points are reduced to two points on the Σ^3 surface by an interpolation on the altitude, and finally these two points are reduced to the desired stress by an interpolation on the weight.

Note that the number FACTOR is used to scale the calculation made in the table look up routine.

3 COMPUTER FLOW DIAGRAM AND PROGRAM

The computer routine was coded in FORTRAN Extended Language with the main program and subroutines arranged as follows:



MAIN - Main Program - Sets NZERO and NPSCT to zero and transfers program control to GUIDE

GUIDE - Subroutine - Initially zeros input and output numbers and after first case zeros output numbers before the calculations are performed. **GUIDE**, the main controlling subroutine, transfers control to **INPUT**, **CALC**, **LDLVL**, **PRINTR**, and **LDCDEF** in turn.

INPUT - Subroutine - Reads in all input data including the VGH histogram and the stress table. There are two formats for reading in floating point numbers and three formats for reading in fixed point numbers. The details of the data input are discussed later in this section.

INAID - Subroutine - Called by **INPUT** and has the purpose of writing out certain input data.

- (1) NRV_I, NRV_Z, NRH, NRW
- (2) FACT_R
- (3) PSIL
- (4) AREAN
- (5) PS
- (6) Stress table
- (7) VGH histogram table
- (8) FVI, FNZ, FH, FW

Also, **INAID** sets NZERO=1 for control of data handling in **GUIDE**

PAGEHD - Subroutine - Writes out page heading including run identification, date and page number

CALC - Subroutine - Computes PPSI and PDPSI

LDLVL - Subroutine - Computes PSIL and FRAC

LDCDEF - Subroutine - Computer ALPHA

TABQ - Subroutine - Called from **CALC** to perform the interpolation discussed in Section IV, B, that computes the stress corresponding to a given indicated airspeed, normal load factor, altitude, and weight.

TABT - Subroutine - called from **CALC** as an alternate to **TABQ** for the interpolation to compute the stress corresponding to a given indicated airspeed, equivalent normal load factor, and altitude.

GAUSS2 - Subroutine - Called from CALC to solve the simultaneous equations that are required to pass second order equations through the points of PPSI so that the differentiation for PDPSI can be performed. The subroutine uses the Gauss-Jordan method for solving the sets of simultaneous equations.

GAUS21 - Subroutine - Called from LUCDEF and is used to solve the set of equations PLD(I) = PS(K,J) * ALPHA(J). This subroutine is identical to GAUSS2 except for a DIMENSION statement change.

PRINTR - Subroutine - Called from GUIDE to write out computed output data. In particular, PRINTR prints

- (1) PPSI
- (2) EXCEED
- (3) HOURS
- (4) PDPSI
- (5) PSILL, FRAC

4 EQUIVALENCE TABLES

The technique that has been used in coding this routine is to place all input and output numbers in blank common. All input and output floating point numbers are called parameters and are contained in P (dimensioned 10,000). All input and output fixed point numbers are called integers and are contained in NTEGER (dimensioned 100). To make the program more easily interpreted, EQUIVALENCE statements are used to provide the P and NTEGER numbers with more recognizable names. The SPECA program parameter and integer tables are given below.

PARAMETER EQUIVALENCE TABLE

P	Dimension	Term	P	Dimension	Term
1	(1)	FMN,FVI	1201	(100)	APDPSI(1,
2	(1)	FNZ	1300		APDPSI(100,
3	(1)	FH	1301	(100)	PSIL(1)
4	(1)	FW	1400		PSIL(100)
5	(1)	FACTØR	1401	(100)	FRAC(1)
6	(1)	HOURS	1500		FRAC(100)
.			1501	(100,25)	PLUS(1,1)
.			4000		PLDS(100,25)
.			4001	(25)	ALPHA(1)
.			4025		ALPHA(25)

P	Dimension	Term	P	Dimension	Term
100	(1)	NT	.		
101	(100)	PSIL(1)	.		
200		PSIL(100)	.		
201	(100)	AREAN(1)	5001	(25)	VII(1)
300		AREAN(100)	5025		VII(25)
301	(25,25)	PS(1,1)	5026	(25)	NZI(1)
925		PS(25,25)	5050		NZI(25)
.			5051	(25)	HI(1)
.			5075		HI(25)
.			5076	(25)	WI(1)
1001	(100)	PPSI(1)	5100	.	WI(25)
1100		PPSI(100)	.		
1101	(100)	PDPSI(1)	.		
1200		PDPSI(100)	6001	(100)	EXCEED(1)
			6100		EXCEED(100)

INTEGER EQUIVALENCE TABLE

NTEGER	Dimension	Term	NTEGER	Dimension	Term
1	(1)	IDENT	.		
2	.	NPF1	.		
3	.	NPF2	.		
4	.	NPF3	56	(2)	NTB41(1)
5		NPF4	57		NTB41(2)
6		NTI4	58	(2)	NTB42(1)
7		NTW4	59		NTB42(2)
8		MONTH	60	(2)	NTB42(1)
9		DAY	61		NTB43(2)
10		YEAR	62	(2)	NTB44(1)
11		NPSIL	63		NTB44(2)
12		NPSILL	64	(1)	NTB21
13		NPS	65	(1)	NTB22
14		NMORE			
15		NRMN			
16		NRNZ			
17		NRH			
18		NRW			
19					
20					
21		NTB			
.					
.					
49		NPAGE			

5 INPUT DATA

All of the input data described below is read into the program by means of the subroutine INPUT. INPUT is a general purpose subroutine for reading data from cards. For this program, the full capabilities of INPUT are not required and consequently there will be some zeros in the input that serve to bypass certain options.

The following deck arrangement is recommended:

14I5 Format

IDENT	NPF1	0	0	0	NT14	NTW4	MUNTH	DAY	YEAR	NPSI	NPSIIL	NPS	21
-------	------	---	---	---	------	------	-------	-----	------	------	--------	-----	----

7I5 Format

NRVI	NRNZ	NRH	NRW	0	0	NIB
------	------	-----	-----	---	---	-----

72H Format

Run Description

72H Format

Run Description

3I5

1	6	1
---	---	---

6E10.3 Format

FVI	FNZ	FH	FW	FACTOR	HOURS
-----	-----	----	----	--------	-------

3I5 Format

101	100 +	1
-----	-------	---

6E10.3 Format

PSIL(1) - PSIL(NPSIL)

3I5 Format

201	200 +	1
NPSILL		

6E10.3 Format

AREAN(1) - AREAN(NPSILL)

If NPS > 1 go to (a)

If NPS = 0 go to (b)

(a)

3I5 Format

301	300+	1
NPS		

6E10.3 Format

PS(1,1) - (PS(NPS,1)

3I5 Format

326	325 +	1
NPS		

6E10.3 Format

PS(1,2) - PS(NPS,2)

3I5 Format

351	350 +	1
NPS		

6E10.3 Format

PS(1,3) - PS(NPS,3)

3I5 Format

301 +	300 +	
25(NPS	(NPS-1)	1
-1)	·25+NPS	

6E10.3 Format

PS(1,NPS) - PS(NPS,NPS)

- (b) If NTI4 > 0 go to (c) to read NI14 table(s). For the first run in a computer input the stress table and the VGH histogram table must be read. Subsequent runs may require no new tables (NTI4 = 0), one new table (NTI4 = 1), or two new tables (NTI4 = 2).

If NTI4 = 0 go to (g)

(c)

5I10 Format

I	NTAB1	NTAB2	NTAB3	NTAB4
---	-------	-------	-------	-------

(Stress table control cards)

6E10.3 Format

TABLE(1) - TABLE(NTAB1)
(indicated airspeeds for the stress table)

6E10.3 Format

TABLE(NTAB1+1) - TABLE(NN12)
(normal load factors for the stress table)

6E10.3 Format

TABLE(NN12+1) - TABLE(NN13)
(altitudes for the stress table)

If NTB = 1 go to (d)

If NTB = 2 go to (e)

(d)

6E10.3 Format

TABLE(NN13+1) - TABLE(NN14)
(weights for the stress table)

6E10.3 Format

TABLE(NN14+1) - TABLE(NF)
(stress amplitudes for the stress table)
(see Section 3.2 for ordering of these entries)

go to (f)

(e)

E10.3 Format

WTTB3

(ref. weight)

6E10.3 Format

TABLE(NN13+1) - TABLE(NF)
(stress amplitudes for the stress table)
(see Section 3.2 for ordering of these entries)

(f)

5I10 Format

2	NT421	NT422	NT423	NT424
---	-------	-------	-------	-------

(VGH histogram control cards)

6E10.3 Format

VII(1) - VII(NT421)
(indicated airspeeds for VGH histogram table)

NZI(1) - NZI(NT422)
(normal load factor for VGH histogram table)

H1(1) - H1(NT423)
(altitudes for VGH histogram table)

W1(1) - W1(NT424)
(weights for VGH histogram table)

$\gamma^a(VII(1),NZI(1),H1(1),W1(1))$ -
 $\gamma^a(VII(NT421),NZI(NT422),H1(NT423),W1(NT424))$
(load occurrences in VGH histogram table)
(see discussion below for ordering of these entries)

(g) END OF FILE

The first card contains 14 fixed point (integer) numbers arranged in 15 fields. These 14 entries in order on this card are

- (1) IDENT - run number
- (2) NPF1 = 3 if $N_p = 1$
= 3 + N_p if $N_p > 1$
- (3) 0
- (4) 0
- (5) 0
- (6) NT14 - the number of quadruple tables to be read (for this count the stress table and the VGH histogram table are each considered quadruple tables.)

- (7) NIW4 = 1 for print of quadruple tables
= 0 otherwise
- (8) MONTH - month in date for page heading
- (9) DAY - day in date for page heading
- (10) YEAR - year in date for page heading
- (11) NPSIL = N_{F_L}
- (12) NPSILL = M
- (13) NPS - The number of control points if $N_p > 1$. NPS = 0
if $N_p = 1$
- (14) 21

The second card contains seven fixed point numbers arranged in 15 fields. In order these entries are

- (1) NRVI = $N_{V_i}^R$
- (2) NRNZ = $N_{n_z}^R$
- (3) NRH = N_h^R
- (4) NRW = N_w^R
- (5) 0
- (6) 0
- (7) NTB = 1 if the load occurrences in the VGH histogram depend on indicated airspeed, normal load factor, altitude, and weight.
NTB = 2 if the load occurrences in the VGH histogram depend on indicated airspeed, equivalent normal load factor, and altitude

The third and fourth cards contain a72H field each for the purpose of run description, etc.

The fifth card contains 1, 6, and 1 in 15 fields

The sixth card contains six floating point numbers arranged in E10.3 fields. These six numbers are placed in the following order:

$$(1) FVI = v_i(N_{V_i} + 1)$$

- (2) FNZ = $n_z(N_{n_z} + 1)$
- (3) FH = $h(N_h + 1)$
- (4) FW = $w(N_w + 1)$
- (5) FACTOR - stress scaling factor
- (6) HOURS - number of hours of data in the VGH histogram

The seventh card contains the three fixed point numbers 101, 100 + NPSIL, 1 in order in 15 fields. NPSIL must not exceed 100.

The next card(s) contains(s) the numbers PSIL(1) through PSIL(NPSIL) in E10.3 fields, six numbers per card.

The next entry contains the fixed point numbers 201, 200 + NPSILL, 1 in order in 15 fields. NPSILL must not exceed 100.

Following this card the floating point numbers AREAN(1) through AREAN(NPSIL), arranged in E10.3 fields, six numbers per card, are entered.

If NPS = 0 then the PS matrix is omitted from the input deck.

If NPS = i then the PS matrix is placed next in the input deck. PS is dimensioned (25,25) and is equivalenced to P such that P(301) = PS(1,1). Therefore, it follows that P(300+NPS) = PS(NPS,i), P(326) = PS(1,2), and P(301+25(NPS-1)) = PS(1,NPS). Consequently the NPS blocks of data are read in as follows:

First block -

The first card contains the fixed point numbers 301, 300+NPS, 1 arranged in 15 fields.

The next entries are the floating point numbers FS(1,1) through FS(NPS,1) in E10.3 fields, six numbers per card.

Second block -

The first card contains the fixed point numbers 326, 325+NPS, 1 arranged in 15 fields.

The next entries are the floating point numbers PS(1,2) through PS(NPS,2) in E10.3 fields, six numbers per card.

.

Nr'Sth block -

The first card contains the fixed point numbers 301+ 25(NPS-1), 300+(NPS-1)(25) + NPS arranged in 15 fields.

The next entries are the floating point numbers PS(1,NFS) through PS(NPS,NFS) in E10.3 fields, six numbers per card.

The remaining entries are the stress table and the VGH histogram table. These entries are prepared as follows:

If I = 1 then the entry is the stress table where there are $NP = NTAB1 \cdot NTAB2 \cdot NTAB3 \cdot NTAB4$ points defined by NTAB1 indicated airspeeds, NTAB2 normal load factors, NTAB3 altitudes, NTAB4 weights. These points are entered as ordinates of the simple graph TABLE which was defined in paragraph 2 of this section.

The first card for the stress table contains five (5) fixed point numbers in 15 fields in the order

- (1) 1
- (2) NTAB1
- (3) NTAB2
- (4) NTAB3
- (5) NTAB4

The next card(s) contain(s) the indicated airspeeds (floating point numbers) TABLE(1) through TABLE(NTAB1) arranged in E10.6 fields, six numbers per card.

The next entries are the normal load factors TABLE(NTAB1 +1, NN12) (see paragraph 2 for definition of arguments) arranged in E10.3 fields six numbers per card.

Next, the card(s) that contain the altitudes TABLE(NN12+1) through TABLE(NN13) arranged in E10.3 fields, six numbers per card are entered in order.

The next entries depend on the number NTB.

If NTB = 1 the card(s) that contain(s) the weights TABLE(NN13+1) through TABLE(NN14) arranged in E10.3 fields, are entered with six numbers per card.

The next card(s) contain(s) the stresses TABLE(NN14+1) through TABLE(NF) arranged in E10.3 fields, six numbers per card. The ordering of the stresses in this entry is defined in paragraph 2 of this section.

If NTB = 2 a card is entered that contains the reference weight WTTB3 in an E10.3 field.

The next card(s) contain(s) the stresses TABLE(NN13+1) through TABLE(NF) arranged in E10.3 fields, six numbers per card. The number NF must not exceed 2000. The ordering of the stresses in this entry is defined in paragraph 2 of this section.
(Note that NTAB4 = 1 for this case.)

This completes the stress table

If I = 2 then the entry is the VGH histogram table where there are NP24 = NT421 · NT422 · NT423 · NT424 regions defined by NT421 indicated airspeed intervals, NT422 normal load factor intervals, NT423 altitude intervals, and NT424 weight intervals.

The first card for the VGH histogram table contains five fixed point numbers in 15 fields in the order

- (1) 2
- (2) NT421
- (3) NT422
- (4) NT423
- (5) NT424

Following this card are the card(s) with the indicated airspeeds (floating point numbers) VII(1) through VII(NT421) arranged in E10.3 fields, six numbers per card.

The next card(s) contain the normal load factors NZI(1) through NZI(NT422) arranged in E10.3 fields, six numbers per card.

Next are the card(s) that contain the altitudes HI(1) through HI(NT423) arranged in E10.3 fields, six numbers per card.

The weight entries WI(1) through WI(NT424) arranged in E10.3 field, six numbers per card, are next.

The final card(s) in the VGI histogram deck are the load occurrences in regions defined by the indicated airspeeds, normal load factors, altitudes, and weights. If i is in $[1, NP]$ then these entries are $\beta(VII(i), NZI(i), HI(i), WI(i))$ through $\beta(VII(NT421), NZI(NT422), HI(NT423), WI(NT424))$ arranged in E10.3 fields, six numbers per card. If i is in $[1, NT421]$, j is in $[1, NT422]$, k is in $[1, NT423]$, and m is in $[1, NT424]$ then the stress that corresponds to $VII(i)$, $NZI(j)$, $FI(k)$, $WI(m)$ is the $((m-1) \cdot NT421 + NT422 + NT423 + (k-1) \cdot NT421 + NT422 + (j-1) \cdot NT421 + i)$ th entry on these cards. The number $NT421 + NT422 + NT423 + NT424 + NT421 \cdot NT422 \cdot NT423 \cdot NT424$ must not exceed 2000.

6 SAMPLE PROBLEM

A sample run is presented for the purpose of acquainting the user with the input data cards and the output. The data used does not represent any particular aircraft or usage. It is assumed that two control points are sufficient in this case to define the full scale aircraft fatigue spectrum. The input cards are as follows:

100	5	0	0	0	2	1	3	30	1973	23	12	2	21
2	2	2	2	0	0	1							
CHECK OUT RUN FOR SPECA PROGRAM													
V G H DATA IN TABLE CONTROL POINT NUMBER 1 (REVISION 2) •													
1	6	1											
650.0	7.0		40000.0		36000.0		1.0		500.0				
101	123	1											
20000.0	22000.0		24000.0		26000.0		28000.0		30000.0				
32000.0	34000.0		36000.0		38000.0		40000.0		42000.0				
44000.0	46000.0		48000.0		50000.0		52000.0		54000.0				
56000.0	58000.0		60000.0		62000.0		64000.0						
201	212	1											
0.05	0.10		0.20		0.25		0.30		0.40				
0.50	0.60		0.70		0.80		0.90		0.95				
301	302	1											
20000.0	35000.0												

326 327 1
25000.0 30000.0

	1	3	3	3	3
300.0	500.0	600.0			
3.0	6.0	8.0			
5000.0	20000.0	35000.0			
25000.0	30000.0	35000.0			
20000.0	22000.0	25000.0	42000.0	43000.0	46000.0
55000.0	57000.0	58000.0	17000.0	18000.0	20000.0
32000.0	34000.0	35000.0	51000.0	53000.0	54000.0
15000.0	17000.0	18000.0	26000.0	28000.0	29000.0
41000.0	42000.0	44000.0	24000.0	26000.0	29000.0
46000.0	47000.0	50000.0	59000.0	61000.0	62000.0
21000.0	22000.0	24000.0	36000.0	38000.0	39000.0
55000.0	57000.0	58000.0	19000.0	21000.0	22000.0
30000.0	32000.0	33000.0	45000.0	46000.0	48000.0
27000.0	29000.0	32000.0	49000.0	50000.0	53000.0
62000.0	64000.0	65000.0	24000.0	25000.0	27000.0
39000.0	41000.0	42000.0	58000.0	60000.0	61000.0
22000.0	24000.0	25000.0	33000.0	35000.0	36000.0
48000.0	49000.0	51000.0			

	2	3	3	3	3
350.0	450.0	550.0			
4.0	5.0	6.0			
10000.0	20000.0	30000.0			
30000.0	32000.0	34000.0			
500.0	1000.0	600.0	1000.0	1100.0	600.0
700.0	770.0	7700.0	100.0	4000.0	600.0
1000.0	100.0	1000.0	700.0	2000.0	600.0
6000.0	1000.0	4000.0	600.0	6000.0	1000.0
700.0	1000.0	6000.0	3000.0	600.0	700.0
1000.0	2000.0	500.0	4000.0	700.0	1000.0
500.0	4000.0	6000.0	700.0	7000.0	7700.0
4000.0	2000.0	700.0	500.0	3000.0	500.0
1000.0	600.0	3000.0	1000.0	500.0	5000.0
700.0	4000.0	600.0	3000.0	4000.0	400.0
1000.0	100.0	500.0	5000.0	5500.0	4000.0
500.0	1000.0	700.0	500.0	5000.0	3000.0
600.0	6000.0	3000.0	2000.0	4000.0	3000.0
1000.0	2000.0	200.0			

100	0	0	0	1	1	8	30	1973	23	12	2	21
-----	---	---	---	---	---	---	----	------	----	----	---	----

2	2	2	0	0	1
---	---	---	---	---	---

CHECK OUT FOR SPECIA PROGRAM

V G H DATA IN TABLE CONTROL POINT NUMBER 2

1	3	3	3	3
---	---	---	---	---

300.0	500.0	600.0		
-------	-------	-------	--	--

3.0	6.0	8.0			
5000.0	20000.0	35000.0			
25000.0	30000.0	35000.0			
10000.0	20000.0	24000.0	36000.0	39000.0	40000.0
45000.0	50000.0	53000.0	17000.0	18000.0	20000.0
25000.0	27000.0	30000.0	51000.0	53000.0	54000.0
15000.0	17000.0	18000.0	26000.0	28000.0	29000.0
32000.0	34000.0	36000.0	25000.0	26000.0	27000.0
42000.0	43000.0	44000.0	55000.0	56000.0	57000.0
21000.0	22000.0	24000.0	36000.0	38000.0	39000.0
55000.0	57000.0	58000.0	19000.0	21000.0	22000.0
30000.0	32000.0	33000.0	45000.0	46000.0	48000.0
27000.0	29000.0	32000.0	49000.0	50000.0	53000.0
62000.0	64000.0	65000.0	24000.0	25000.0	27000.0
39000.0	41000.0	42000.0	58000.0	60000.0	61000.0
22000.0	24000.0	25000.0	33000.0	35000.0	36000.0
48000.0	49000.0	51000.0			

Based on this input the following output listing was obtained.

RUN NO 100 DATE 6/20/1971 PAGE NO 1

CHECK OUT RUN FOR SPECIA PROGRAM
VGM DATA IN TABLE CONTROL POINT NUMBER 1 (REVISION 2)

WISCONSIN SUBDIVISIONS

Kewa 1	2
Kewa 2	2
Kewa 3	2
Kewa 4	2

LOAD MAGNIFICATION FACTOR = 1,0000

INTERVAL LOAD LEVELS FOR INTEGRATION OF JOINT DENSITY FUNCTION

1	2.0000E+04	2	2.2000E+04	3	2.4000E+04	4	2.6000E+04
5	2.6000E+04	6	3.0000E+04	7	3.2000E+04	8	3.4000E+04
9	3.6000E+04	10	3.8000E+04	11	4.0000E+04	12	4.2000E+04
13	4.4000E+04	14	4.6100E+04	15	4.8000E+04	16	5.0000E+04
17	5.2000E+04	18	5.4100E+04	19	5.6000E+04	20	5.8000E+04
21	6.0000E+04	22	6.2000E+04	23	6.4000E+04	24	0.

CUMULATIVE AREA'S OF LOAD PROBABILITY DENSITY FUNCTION

1	2.00 001 02	2	1.00000E-01	3	2.00000E-01	4	2.50000E-01
5	3.00 001 01	6	4.00000E-01	7	5.00000E-01	8	6.00000E-01
9	7.00 001 01	10	6.00000E-01	11	9.00000E-01	12	9.50000E-01

PUN NO 100 DATE 8/10/1973

PAGE NO 2

QUADRUPLE TABLE NO. 1

FRT VS VT, N7, M1, W

300.0	N7	600.0	600.0
3,000.0	N7	6,000.0	6,000.0
30,000.	M	30,000.	30,000.
300.0	N	20000.	35000.
25000.	M	30000.	35000.
	PST		
20010.	21100.	25000.	30000.
32030.	44200.	35100.	51000.
41000.	47100.	46100.	24000.
21000.	27000.	26100.	36000.
30030.	37300.	37100.	45000.
67030.	64100.	65100.	24000.
22030.	24100.	25000.	31000.

RUN NO 100 DATE 8/30/1973 PAGE NO 4

INTERNAL LOAD CUMULATIVE PROBABILITY FUNCTION					
LOAD	CUM PROB	LOAD	CUM PROB	LOAD	CUM PROB
2.46930E+00	1.00000E+00	2.200000E+00	1.00000E+00	2.400000E+00	1.00000E+00
2.66944E+00	9.41014E-01	2.800000E+00	9.30656E-01	3.000000E+00	9.31126E-01
3.20033E+00	8.50719E-01	3.400000E+00	5.44037E-01	3.600000E+00	5.22759E-01
3.80000E+00	3.22178E-01	4.000000E+00	2.44392E-01	4.200000E+00	1.73864E-01
4.40000E+00	1.14117E-01	4.600000E+00	7.87654E-02	4.800000E+00	3.48610E-02
5.00000E+00	1.78710E-02	5.200000E+00	1.44347E-01	5.400000E+00	1.40771E-01
5.40000E+00	0.	5.600000E+00	0.	5.800000E+00	0.
6.200000E+00	0.	6.400000E+00	0.	6.600000E+00	0.

RUN NO. 100 DATE 8/30/1973 PAGE NO. 5

CUMULATIVE NUMBER OF EXCEEDANCES PER 1000 HRS		LOAD	EXCEEDANCES	LOAD	EXCEEDANCES	LOAD	EXCEEDANCES
2.00000E+04	3.47740E+05	2.00000E+04	3.45740E+05	2.40000E+04	3.45740E+05	2.80000E+04	3.45740E+05
2.60000E+04	3.31775E+05	3.20000E+04	3.21750E+05	3.40000E+04	3.21750E+05	3.60000E+04	3.17522E+05
3.20000E+04	2.31750E+05	3.40000E+04	1.601025E+05	3.60000E+04	1.601025E+05	4.20000E+04	1.61655E+05
3.80000E+04	1.11310E+05	4.00000E+04	8.43775E+04	4.40000E+04	8.43775E+04	4.80000E+04	8.18775E+04
4.40000E+04	4.046250E+04	4.60000E+04	2.723250E+04	5.00000E+04	6.37500E+02	5.40000E+04	6.25190E+01
5.00000E+04	6.102500E+03	5.60000E+04	0.	5.110000E+04	0.	6.00000E+04	0.
5.60000E+04	0.	6.40000E+04	0.	6.40000E+04	0.	6.00000E+04	0.
6.40000E+04	0.						

BASED ON 505.00 HOURS

BUN N#	100	DATE	8/30/1973	PAGE NO	6
INTERNAL LOAD PENETRABILITY FUNCTION					
LOAD	PCN	DEF	LOAD	PCN	DEF
2.000000E+04	1.95772AF-14	2.200000E+04	1.552652E-19	2.400000E+04	6.745227E-06
2.437130E+04	1.731640E-15	2.400000E+04	3.716743E-05	3.000000E+04	6.114612E-05
1.203700E+04	7.186190E-05	1.400000E+04	6.54201E-05	3.600000E+04	5.546919E-05
1.030291E+04	6.450541E-05	4.000000CF+04	3.777456E-05	4.200000F+04	3.155101E-05
6.462010E+04	2.71911E-05	4.600000E+04	1.974104E-05	4.900000E+04	1.523546E-05
6.000000E+04	0.7200057F-05	5.200000E+04	4.41nH29E-06	5.400000E+04	4.6n467RF-07
5.602100E+04	8.71nH29E-06	5.800000E+04	0.	6.000000E+04	0.
6.7030005F+04	0.	6.400000E+04	0.		

RUN NO. 100 DATE 6/30/1971 PAGE NO. 7

REFLCTIC LOADING FRACTIONS

LOAD	FRACTION	LOAD	FRACTION	LOAD	FRACTION
2.76294E+04	7.50000E-02	2.672792E+04	7.50000E-02	3.043048E+04	7.50000E-02
3.11111E+04	5.00000E-02	1.18050F+04	7.50000E-02	3.317683E+04	1.00000E-01
3.464790E+04	0.133000E-01	3.644536E+04	1.00000E-01	3.858916E+04	1.00000E-01
6.120375E+04	1.00000E-01	4.492567E+04	7.50000E-02	4.733516E+04	7.50000E-02
TOTAL LOAD CYCL S = 172870.					

PUN NO 100 DATE 8/18/1973 PAGE NO 8

CHECK OUT FOR OPERA PROGRAM

VGM DATA IN FILE CONTROL POINT NUMBER 2

MICRODATA SURVEYS

NOVY = 2

NONV = 2

NONW = 2

NONN = 2

LOAN MAGNIFICATION FACTOR = 1.0000

INTERPOLAL LOAD LEVELS FOR INTEGRATION OF JOINT DENSITY FUNCTION

1	2.00E+04	2	2.20000E+04	3	2.40000E+04	4	2.60000E+04
5	2.00E+04	6	3.00000E+04	7	3.20000E+04	8	3.40000E+04
9	3.00E+04	10	3.20000E+04	11	3.40000E+04	12	3.60000E+04
13	4.00E+04	14	4.80000E+04	15	4.80000E+04	16	5.00000E+04
17	5.20000E+04	18	5.40000E+04	19	5.60000E+04	20	5.80000E+04
21	6.00000E+04	22	6.20000E+04	23	6.40000E+04	24	6.

CUMULATIVE AREAS OF LOAN PROBABILITY DENSITY FUNCTION

1	5.00000E-01	2	1.00000E-01	3	2.00000E-01	4	2.50000E-01
5	1.00000E-01	6	6.00000E-01	7	5.00000E-01	8	6.00000E-01
9	7.00000E-01	10	6.00000E-01	11	9.00000E-01	12	9.50000E-01

प्राचीन विद्या का अध्ययन एवं उसका सम्बन्ध
प्राचीन विद्या का अध्ययन एवं उसका सम्बन्ध

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PUN NO	106	DATE	07/30/1973	PAGE NO	10
QUADRUPLE TARIFF NO. 1					
PST VS VI, W7, W8, W9					
VI					
100.0	N7	009.0	600.0		
3.0000	N	6.0000	8.0000		
500.0	N	2000.0	3500.0		
2000.	N	10000.	35000.		
PST					
100.0		200.0	24000.	36000.	19000.
24000.		27000.	51000.	54000.	13000.
36000.		36000.	51000.	16000.	26000.
100.0		16000.	26000.	10000.	10000.
24000.		25000.	26000.	42000.	40000.
36000.		26000.	39000.	39000.	56000.
100.0		24000.	36000.	50000.	57000.
24000.		24000.	36000.	50000.	21000.
36000.		36000.	46000.	27000.	27000.
100.0		37000.	46000.	29000.	49000.
24000.		37000.	46000.	32000.	50000.
36000.		46000.	56000.	42000.	57000.
100.0		65000.	25000.	39000.	50000.
24000.		65000.	31000.	40000.	61000.
36000.		25000.	31000.	49000.	60000.
24000.		24000.	31000.	51000.	

RIN NO. 100 DATE 6/30/1971 PAGE NO. 11

QUADRUPLE TABLE NO. 2

WISTJ VS VIT, +Z, H, V

VIT = 150.0 450.0 550.0

4.0000 5.0000 6.0010

10000. 20000. 30000.

50000. 100000. 300000.

500. 1000. 600.

1000. 1500. 2000.

2000. 2500. 3000.

3000. 4000. 5000.

4000. 5000. 6000.

5000. 6000. 7000.

6000. 7000. 8000.

7000. 8000. 9000.

8000. 9000. 10000.

9000. 10000. 11000.

10000. 11000. 12000.

12000. 13000. 14000.

14000. 15000. 16000.

16000. 17000. 18000.

18000. 19000. 20000.

20000. 21000. 22000.

22000. 23000. 24000.

24000. 25000. 26000.

26000. 27000. 28000.

28000. 29000. 30000.

30000. 31000. 32000.

32000. 33000. 34000.

34000. 35000. 36000.

36000. 37000. 38000.

38000. 39000. 40000.

40000. 41000. 42000.

42000. 43000. 44000.

LAST AND CLEAREST IN TABLE 2

VIT = 0.5000000000000000

FV1 = .7010000000000000

FV2 = .4000000000000000

FW = .5000000000000000

FW = .5000000000000000

BIN NO 100 DATE 8/10/1973 PAGE NO 12
 TTFONAL LOAN CUMULATIVE PROBABILITY FUNCTION
 LOAN CUM PROB
 2.00000E+00 1.30000E+00
 2.50000E+00 9.01101E-01
 3.00000E+00 6.11111E-01
 3.50000E+00 3.66667E-01
 4.00000E+00 2.33333E-01
 4.50000E+00 1.48148E-01
 5.00000E+00 8.77778E-02
 5.50000E+00 5.22222E-02
 6.00000E+00 2.77778E-02
 6.40000E+00 1.40000E-02
 6.80000E+00 6.00000E-03
 7.20000E+00 2.22222E-03
 7.50000E+00 8.00000E-04
 7.80000E+00 3.00000E-04
 8.10000E+00 1.00000E-04
 8.40000E+00 3.33333E-05
 8.70000E+00 1.00000E-05
 9.00000E+00 3.00000E-06

LOAD CUM PROB
 2.20000E+00 1.00000E+00
 2.80000E+00 9.30456E-01
 3.40000E+00 5.41346E-01
 4.00000E+00 2.33335E-01
 4.60000E+00 6.49657E-02
 5.20000E+00 7.55941E-04
 5.80000E+00 0.
 6.40000E+00 0.
 6.00000E+00 0.
 6.60000E+00 0.
 7.20000E+00 1.60771E-04
 7.80000E+00 0.
 8.40000E+00 0.
 9.00000E+00 0.

RUN NO 100 DATE 8/30/1973 PAGE NO 13

CUMULATIVE NUMBER OF EXCEEDANCES PEP 1000 MPS			
LOAD	EXCEEDANCES	LOAD	EXCEEDANCES
2.000000E+00	1.551000E+00	2.200000E+00	3.557500E+005
2.400000E+00	3.191775E+005	2.600000E+00	3.217450E+005
3.100000E+00	2.103771E+005	3.400000E+00	1.811650E+005
4.100000E+00	1.108525E+005	4.600000E+00	8.276500E+004
5.400000E+00	1.790375E+004	6.600000E+00	2.261250E+004
5.000000E+00	1.637500E+003	5.200000E+00	2.625000E+002
5.400000E+00	0.	5.800000E+00	0.
6.200000E+00	0.	6.400000E+00	0.

BASED ON 500,000 HOURS

RUN NO. 100 DATE 8/10/1971 PAGE NO. 16

INTERNAL LOAD PROBABILITY DENSITY FUNCTION		LOAD	PROB OF N	LOAD	PROB OF N
LOAD	PROB OF N	2.000000E+04	6.562652E-19	2.400000E+04	6.7465227E-05
2.45729E-18	1.45729E-04	2.000000E+04	3.739762E-15	2.400000E+04	6.172227E-05
2.45729E-18	1.73160E-05	2.000000E+04	5.51711E-05	3.000000E+04	5.5.1711E-05
2.45729E-18	2.000000E+05	2.000000E+04	6.58609E-05	3.490000E+04	3.27279E-05
3.200000E+04	7.25556E-05	2.000000E+04	3.49714E-05	4.200000E+04	1.50579E-05
3.200000E+04	8.71604E-05	2.000000E+04	3.49714E-05	4.600000E+04	1.50579E-05
3.200000E+04	9.52107E-05	2.000000E+04	2.01617E-05	5.400000E+04	1.4941C5E-02
3.200000E+04	1.052107E-05	2.000000E+04	2.01617E-05	6.000000E+04	0.
4.400000E+04	2.57491E-05	2.000000E+04	1.1304E2F-06	5.400000E+04	1.4941C5E-02
4.400000E+04	5.000000E-06	2.000000E+04	0.	6.000000E+04	0.
5.000000E+04	6.76719E-06	2.000000E+04	0.	6.000000E+04	0.
5.000000E+04	4.51929E-06	2.000000E+04	0.	6.000000E+04	0.
6.200000E+04	0.	2.000000E+04	0.	6.000000E+04	0.

DATE 8/30/1971 B/M NO 100 PAGE NO 15

SUCESOS | LOADING FREIGHTONS

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CYCLIC LOADING FRACTION	LOAD	FRACTION		FRACTION
		L _{CAC}	F _{CAC}	
2.74204E-01	7.50000E-02	2.47316E-01	7.50000E-02	7.50000E-02
1.10111E-01	3.00000E-02	1.17753E-01	7.50000E-02	3.00000E-02
1.10111E-01	1.00000E-02	1.63772E-01	1.00000E-02	1.00000E-02
1.10111E-01	3.33333E-03	1.72027E-01	3.33333E-03	3.33333E-03
1.10111E-01	1.00000E-03	2.50000E-01	1.00000E-03	1.00000E-03

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INPUT NO.	DATA	INPUT NO.
66119-000	COEFFICIENTS FOR FREQUENCY LEVEL NO. 0.	2.6919955000 -2.0496948000
66119-001	COEFFICIENTS FOR FREQUENCY LEVEL NO. 1.	2.6919955000 -2.1218160000
66119-002	COEFFICIENTS FOR FREQUENCY LEVEL NO. 2.	2.6919955000 -2.1939370000
66119-003	COEFFICIENTS FOR FREQUENCY LEVEL NO. 3.	2.6919955000 -2.2660580000
66119-004	COEFFICIENTS FOR FREQUENCY LEVEL NO. 4.	2.6919955000 -2.3381790000
66119-005	COEFFICIENTS FOR FREQUENCY LEVEL NO. 5.	2.6919955000 -2.4103000000
66119-006	COEFFICIENTS FOR FREQUENCY LEVEL NO. 6.	2.6919955000 -2.4824210000
66119-007	COEFFICIENTS FOR FREQUENCY LEVEL NO. 7.	2.6919955000 -2.5545420000
66119-008	COEFFICIENTS FOR FREQUENCY LEVEL NO. 8.	2.6919955000 -2.6266630000
66119-009	COEFFICIENTS FOR FREQUENCY LEVEL NO. 9.	2.6919955000 -2.6987840000
66119-010	COEFFICIENTS FOR FREQUENCY LEVEL NO. 10.	2.6919955000 -2.7709050000
66119-011	COEFFICIENTS FOR FREQUENCY LEVEL NO. 11.	2.6919955000 -2.8430260000
66119-012	COEFFICIENTS FOR FREQUENCY LEVEL NO. 12.	2.6919955000 -2.9151470000
66119-013	COEFFICIENTS FOR FREQUENCY LEVEL NO. 13.	2.6919955000 -2.9872680000
66119-014	COEFFICIENTS FOR FREQUENCY LEVEL NO. 14.	2.6919955000 -3.0593890000
66119-015	COEFFICIENTS FOR FREQUENCY LEVEL NO. 15.	2.6919955000 -3.3397370000

SECTION IV

EXAMPLE PROBLEM - F-4 STRESS SPECTRUM FOR POSITIVE LOAD FACTORS

The data base for this problem is four quarters of VGH data starting with the second quarter of 1972 and finishing with the first quarter of 1973. The VGH histogram intervals for these data are the following:

Indicated airspeed (knots)
150, 200, 250, 300, 350, 400, 450, 500, 550, 625, and
700

Normal load factor (equivalent)
1.4, 1.8, 2.2, 2.6, 3.0, 3.8, 4.6, 5.4, 6.6, 7.8, and 9.0

Altitude (feet)
0, 1000, 2000, 5000, 10,000, 15,000, 20,000, 30,000,
40,000, and 50,000

Weight (pounds)
37,500 (reference weight)

The stress table was set up with the following indicated airspeed, normal load factor, altitude, and weight combinations:

Indicated airspeed (knots)
175, 225, 275, 325, 375, 425, 475, 525, 575, and 625

Normal load factor
2.4, 2.8, 3.4, 4.2, 5.0, 6.0, 7.2, and 8.9

Altitude (feet)
500, 1500, 3500, 7500, 12500, 17500, 25000, and 35000

Weight (pounds)
37,500

The VGH histogram table was made up using all of the available data for the air-to-air and air-to-ground operations for the four quarters without distinguishing the various F-4 models except that only the unslatted configurations were considered. The numbers of hours of data in each category and their corresponding numbers of positive and negative load occurrences are shown in Table 1.

The number of stress exceedances per 1000 hours for load reference station (LRS) 180, defined in Figure 1 is shown in Figure 2 through Figure 7. Figure 2 through Figure 5 shows the variation from quarter to quarter of the VGH data. The stress exceedance graphs appear to show a small degree of scatter except for the SEA air-to-air first quarter where there was an overt change in the mission although it was still categorized as air-to-air. The four quarters of data are combined in Figures 6 and 7 to show the differences between the CONUS and SEA in the air-to-air operation and the air-to-ground operation.

SECTION V CONCLUSIONS

The procedure described in this report can eliminate much of the uncertainty that can occur in the derivation of the maneuver load stress spectrum. For new aircraft an estimate must be made of the VGH histogram to obtain the spectrum. This estimate can be updated during Task V of ASIP to derive a better estimate for the operational life of the fleet. This procedure can be immediately applied to fleet tracking by computing the conditional probability of exceeding a stress level given the normal load factor.

The application to full scale aircraft testing makes use of the assumption that the stress is matched at a specified number of control points by a linear combination of the same number of balanced loading conditions. This technique is believed to be more accurate than the usual process of a damage match at the specified control points in that the troublesome damage calculation is eliminated. The stress spectra at points other than control points are presumed to be matched satisfactorily by using representative loading conditions. It is, of course, theoretically better to use all points of the sky that occur in the VGH histogram. This, however, may be impractical due to test equipment limitations.

The procedure as applied to the F-4 fleet indicates that in general the stress spectra do not show significant changes from quarter to quarter. Also, when an operational change is made the method will reflect that change. When CONUS and SEA data are compared there appears to be a reasonably good correlation between the spectra generated in training and the spectra generated in combat.

TABLE 1. F-4 VGH DATA SUMMARY

PERIOD	TYPE	HOURS	+ COUNTS	- COUNTS	TOTAL COUNTS
2Q 72	CONUS AA	196.87	13981	4541	18522
2Q 72	SEA AA	65.84	4047	662	4709
2Q 72	CONUS AG	251.70	30723	9432	40155
2Q 72	SEA AG	1248.94	93027	13258	106285
3Q 72	CONUS AA	290.22	17470	5259	22729
3Q 72	SEA AA	393.26	30842	6366	37208
3Q 72	CONUS AG	469.64	38968	9934	48902
3Q 72	SEA AG	802.74	66446	12485	78931
4Q 72	CONUS AA	184.92	9404	3138	12542
4Q 72	SEA AA	164.35	7862	1933	9795
4Q 72	CONUS AG	89.16	5959	1265	7224
4Q 72	SEA AA	502.09	28254	4819	33073
1Q 73	CONUS AA	123.18	7983	2231	10214
1Q 73	SEA AA	133.96	6100	1358	7458
1Q 73	CONUS AG	194.38	17828	4001	21829
1Q 73	SEA AG	933.87	42342	8229	50571

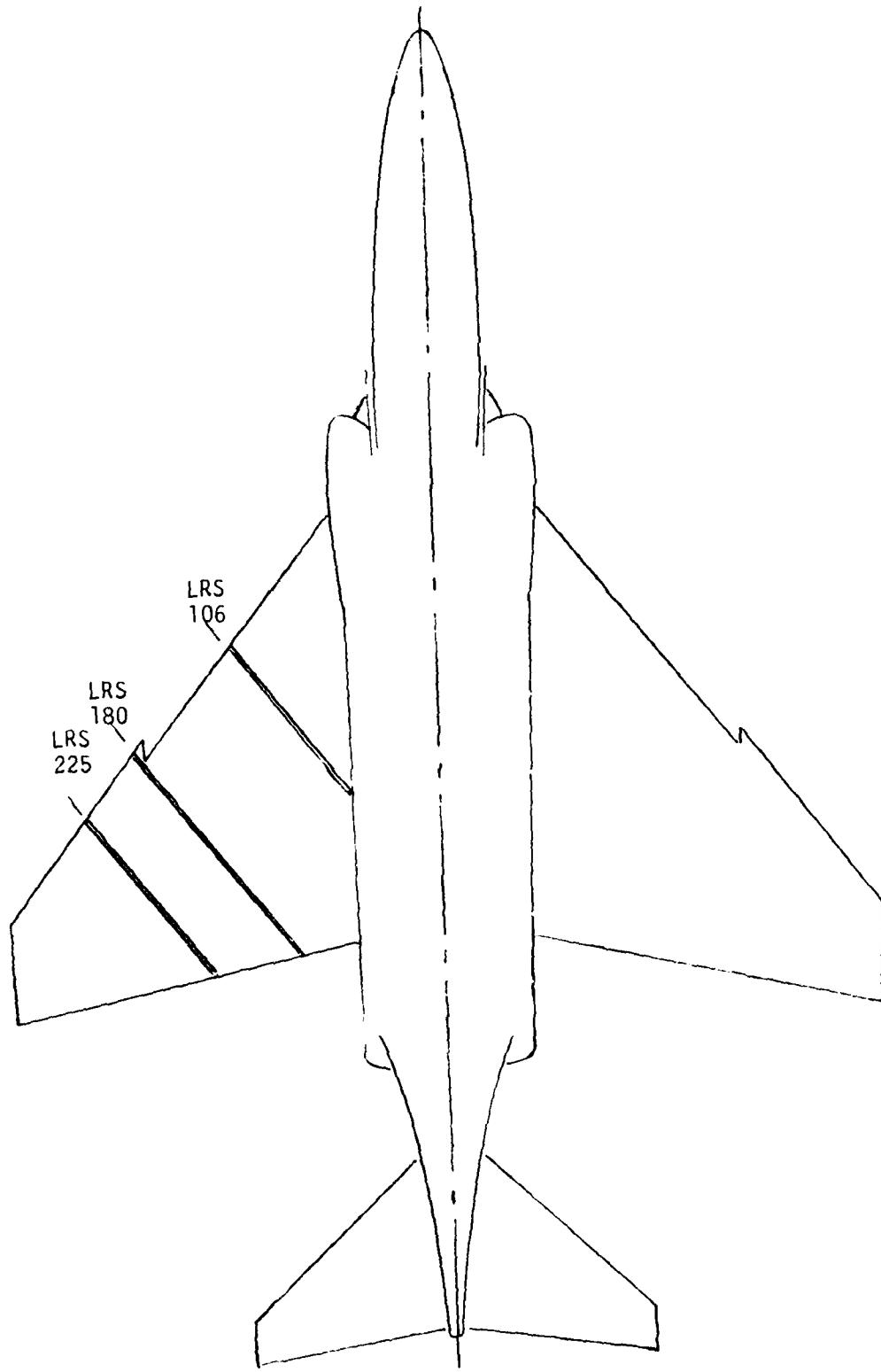


Figure 1. F-4 Wing Load Reference Station Locations

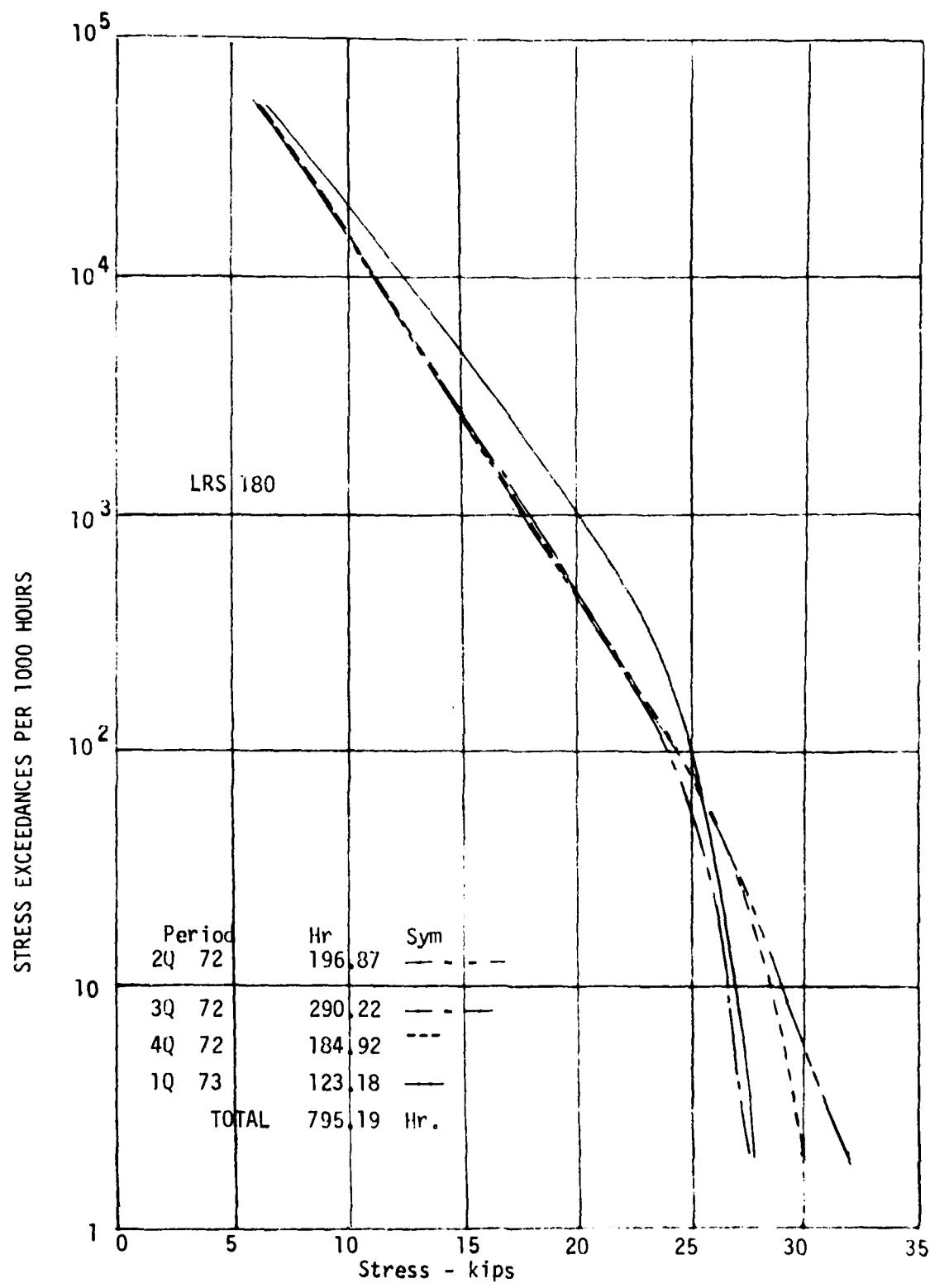


Figure 2. F-4 Spectra - CONUS Air-to-Air (All Models)

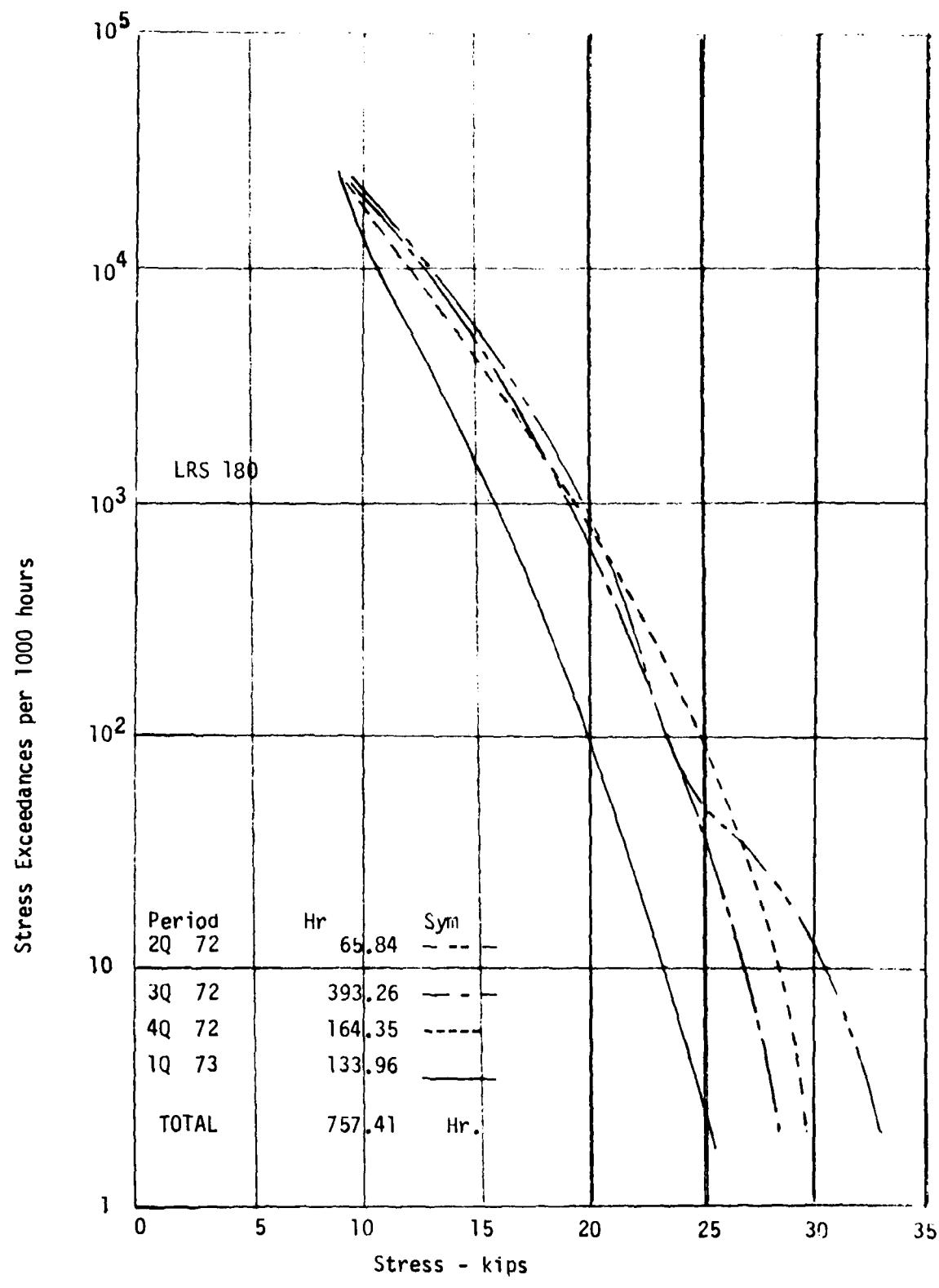


Figure 3. F-4 Spectra - SEA Air-to-Air (All Models)

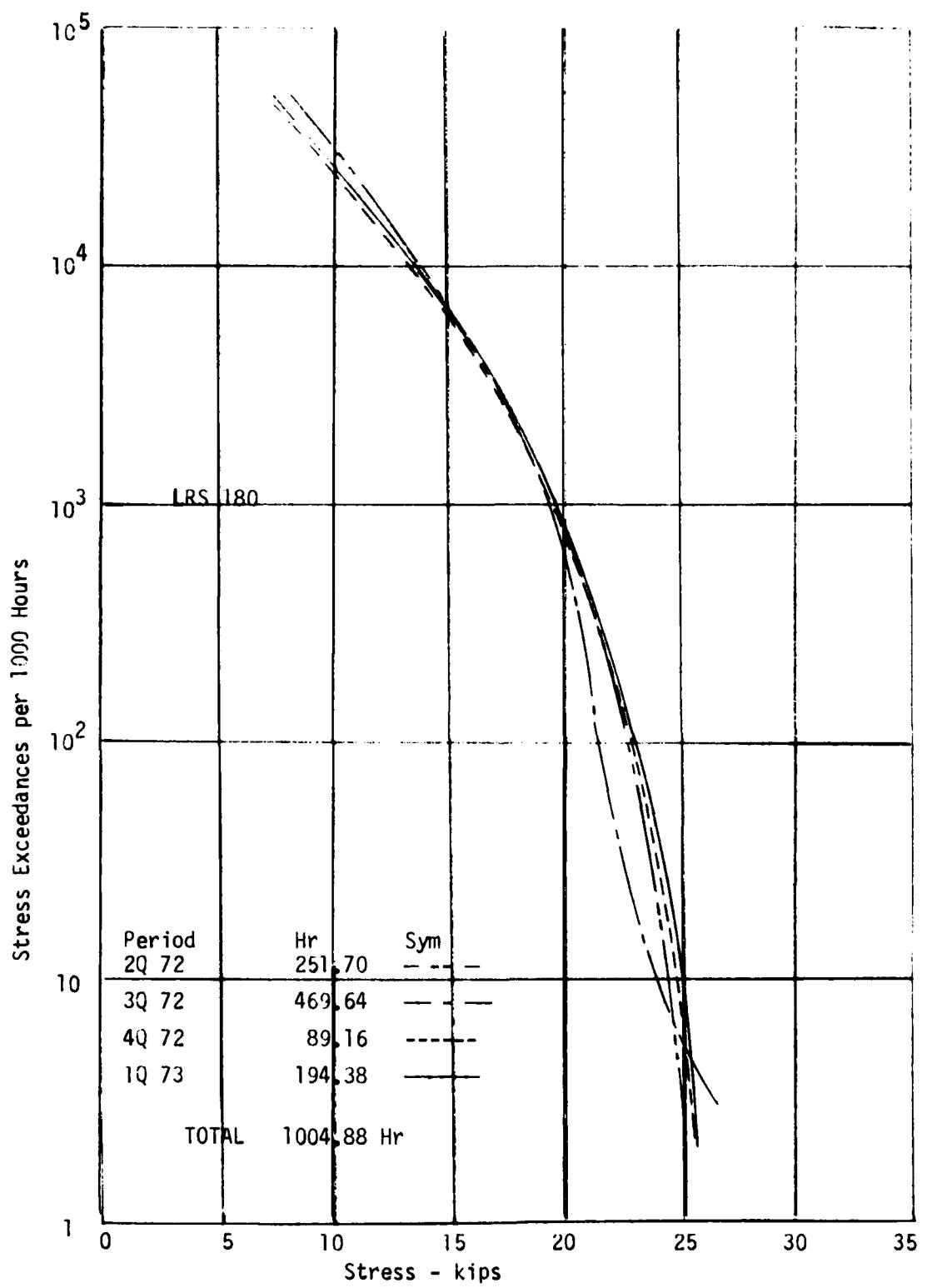


Figure 4. F-4 Spectra - CONUS Air-to-Ground (All Models)

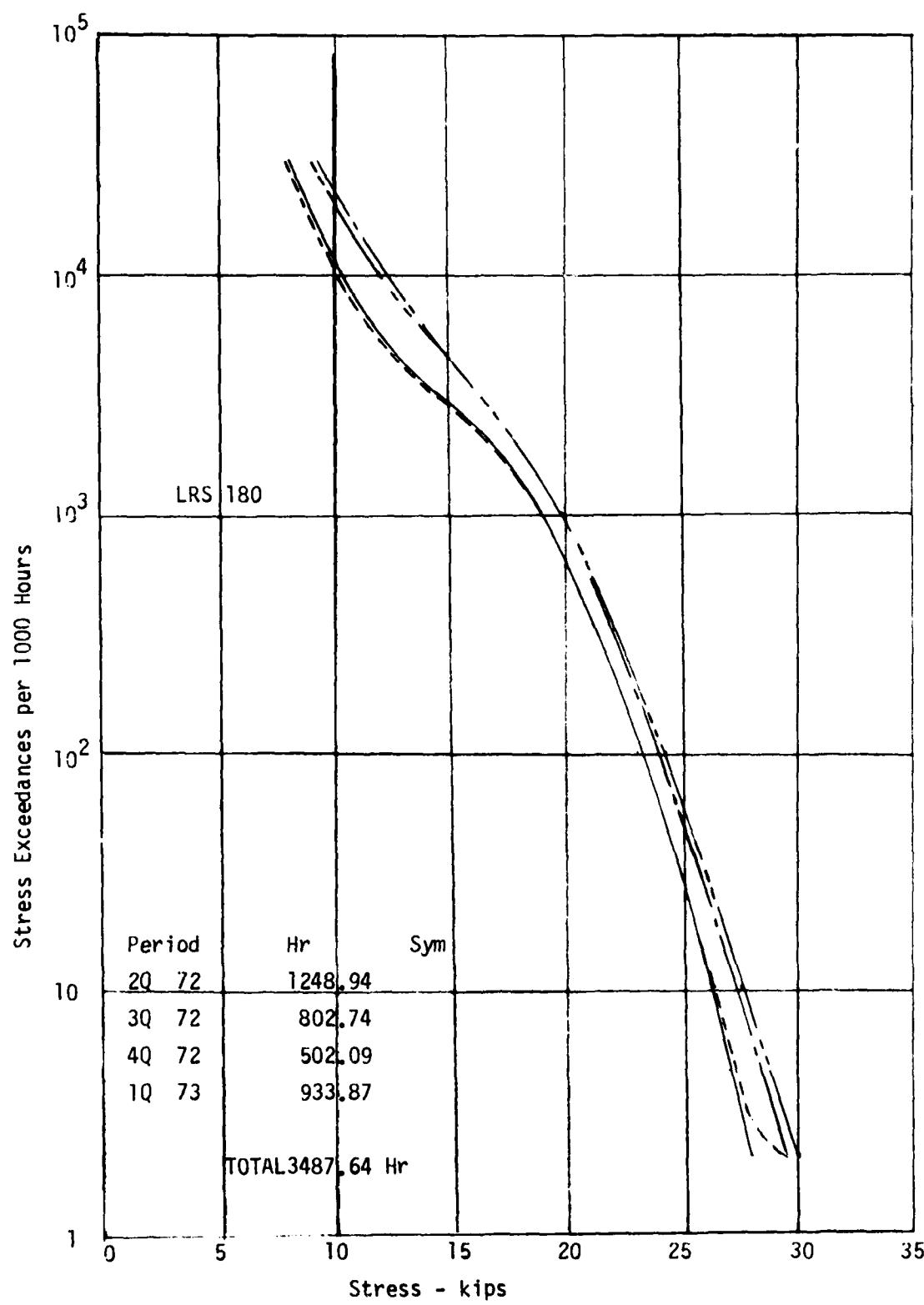


Figure 5. F-1 Spectra - SEA Air-to-Ground (All Models)

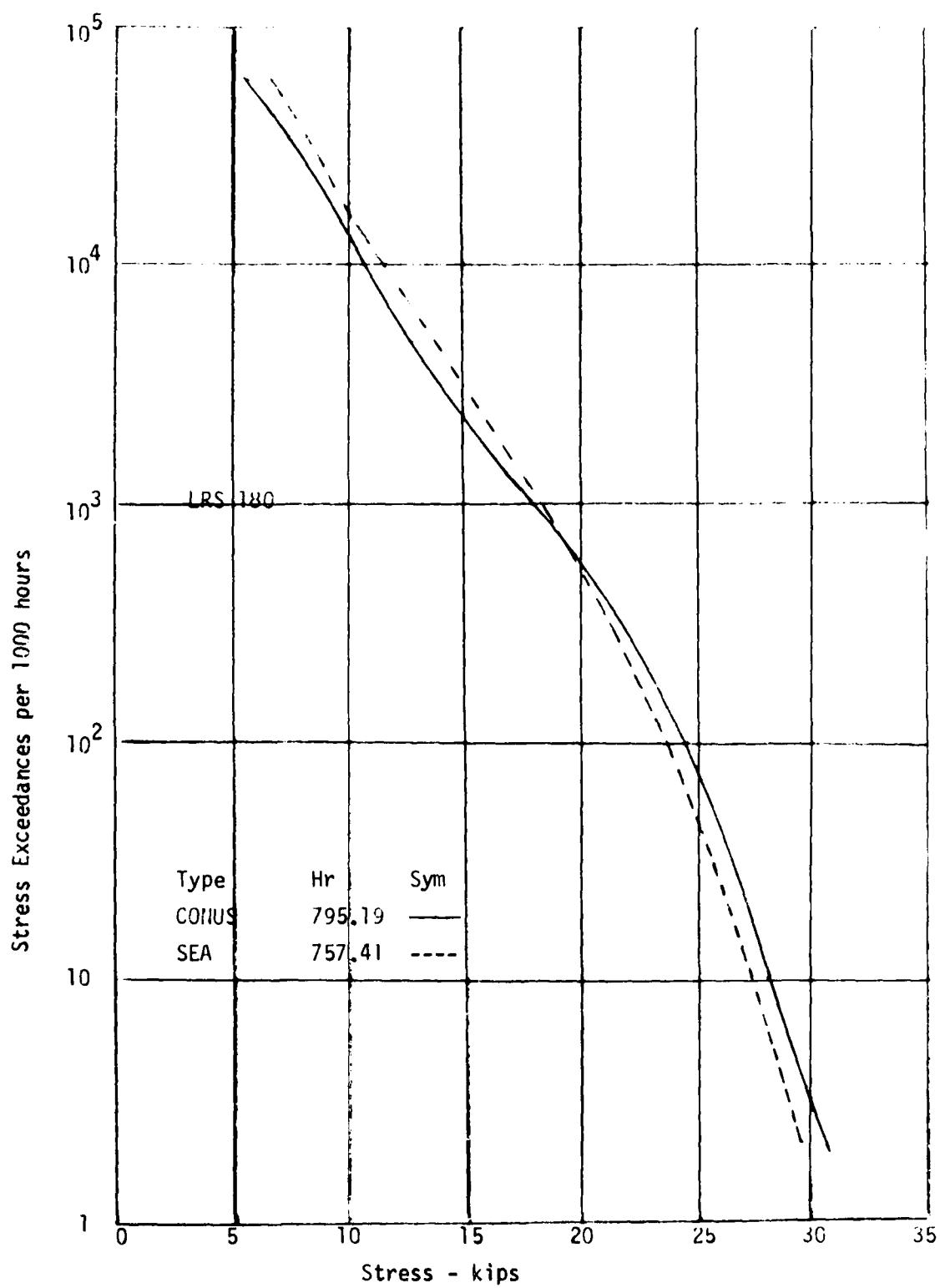


Figure 6. F-4 Spectra - Air-to-Air (All Models)
for One Year of VGH Data

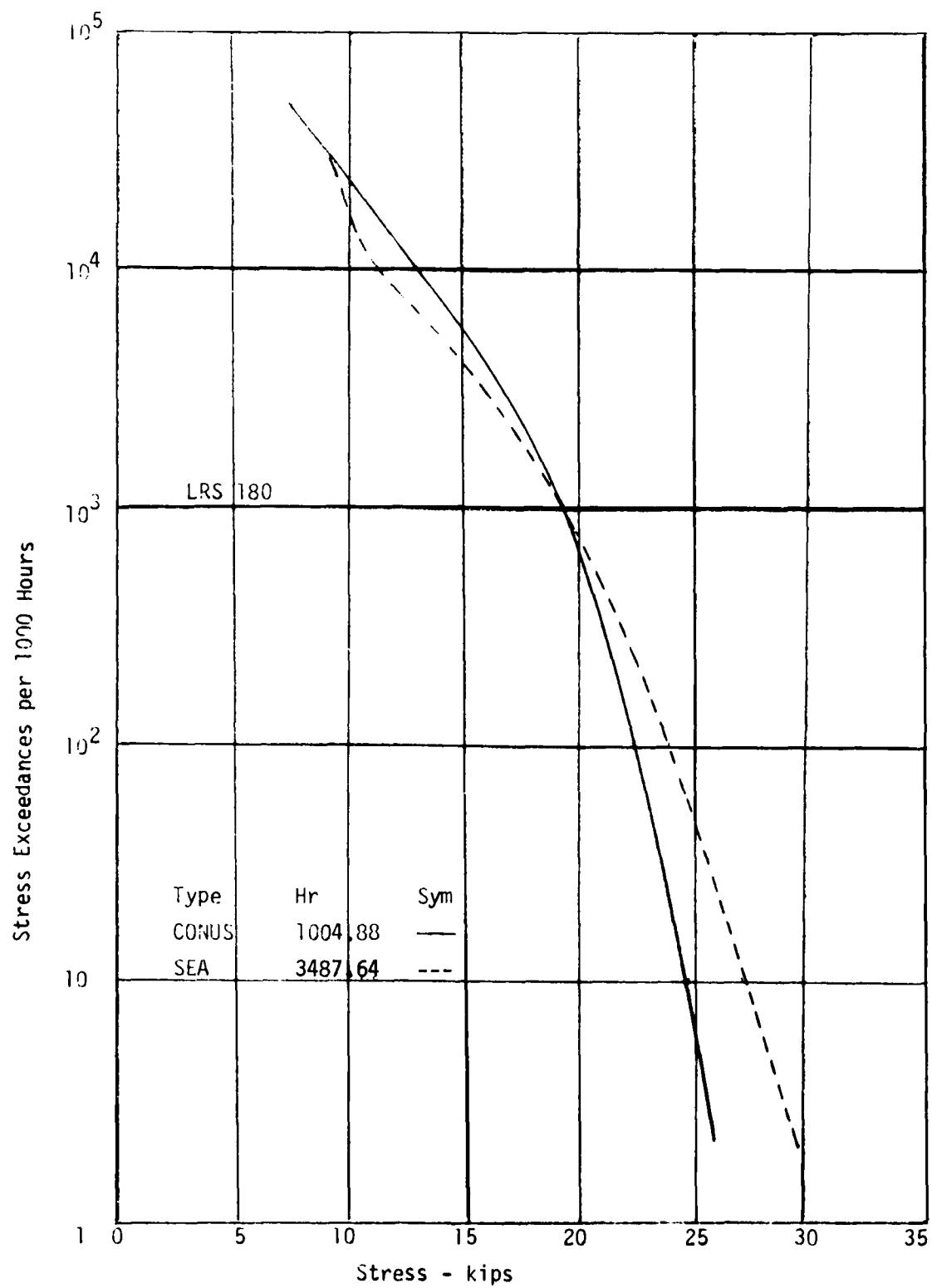


Figure 7. F-4 Spectra - Air-to-Ground (All Models)
for One Year of VGH Data

APPENDIX - SPECA PROGRAM LISTING

The listing given below is a FORTRAN extended language routine. This listing contains all of the statements for the version described in the Introduction of this report. Section 3.3 gives a brief description of each of the subroutines in this listing.

```
PROGRAM SPECIFY INPUT, OUTPUT, TAPE INPUT, TAPE OUTPUT  
C PROGRAM FOR COMPUTING AIRCRAFT INTERNAL LOAD PROBABILITY  
C DENSITY FUNCTIONS  
REVISION 2 COMMON P1100001, N11001001, T110012001, MAIN1  
5      1 TA0121500.1) EQUIVALENCE (N11001001, NZERO), (N11001001, NPSET)  
      NZERO = 0  
      NPSET = 0  
      CALL GUIDF  
      GO TO 10  
      ENDF  
10      2L
```

SUBROUTINE GUIDE

PLT/A -

001-1

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C - SUBROUTINE FOR CALLING INPUT DATA AND CALCULATING ROUTINES

COMMON F10001, NTEGER100, TABLE4(2000,2).

G10E 1

5 1 TABLE2(500,1)

G10F 2

CONVALUE (INTEGER13), MPS1

G10E 3

CONVALUE (INTEGER48), NZERO

G10E 31

CONVALUE (REAL48), FACTOR

G10E 32

IF (NZERO) 60, 10

G10F 44

IF (NZERO) 60, 10

G10E 5

DO 20 I = 1, 10000

G10E 6

PI13 = 0.0

G10E 7

DO 30 I = 1, 100

G10E 8

NIFGR11 = 0

G10F 61

GO TO 46

G10E 9

DO 40 I = 1001, 10000

G10E 91

PI13 = 0.0

G10F 92

FACTOR = 1.0

G10E 93

CALL INPU

G10F 10

CALL CALC

G10F 11

CALL LDVL

G10E 111

CALL PRINTP

G10E 12

IF (INPT) 50, 60, 50

G10E 121

CALL LNOUT

G10E 122

RETURN

G10E 13

END

G10E 14

SUBROUTINE INPUT

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```

      C   SUBROUTINE IN.    TABS, ARRAYS, AND TABLES      DEIN 1
      C   SUBROUTINE FOR INPUT OF    COMMON F10000, NTEGFR1000, TABLE42000,20.  DEIN 4
      C   YANL2500,11.    INTEGER MONTH      DEIN 5
      6      INTEGER MONTH      DEIN 51
      DIMENSION NTA43(21), NTB42(21), NTB43(21), NTA64(21)  DEIN 6
      EQUIVALENCE (P1900, MTB3)  DEIN 10
      EQUIVALENCE (NTEGER11, INENT1), (NTEGER12, NPF11).  DEIN 10
      EQUIVALENCE (NPF13, NPF21), (NTEGER14, NPF31), (NTEGER15, NPF41).  DEIN 11
      EQUIVALENCE (NPF16, NTF11), (NTEGER16, NTF31), (NTEGER17, NTF41).  DEIN 12
      EQUIVALENCE (NTEGER18, NTF51), (NTEGER19, NTF61), (NTEGER20, NTF71).  DEIN 13
      EQUIVALENCE (NTEGER21, NTF81), (NTEGER22, NTF91), (NTEGER23, NTF101).  DEIN 14
      EQUIVALENCE (NTEGER24, NTF111), (NTEGER25, NTF111), (NTEGER26, NTF111).  DEIN 15
      EQUIVALENCE (NTEGER27, NTF111), (NTEGER28, NTF111), (NTEGER29, NTF111).  DEIN 16
      EQUIVALENCE (NTEGER30, NTF111), (NTEGER31, NTF111), (NTEGER32, NTF111).  DEIN 17
      EQUIVALENCE (NTEGER33, NTF111), (NTEGER34, NTF111), (NTEGER35, NTF111).  DEIN 18
      EQUIVALENCE (NTEGER36, NTF111), (NTEGER37, NTF111), (NTEGER38, NTF111).  DEIN 19
      EQUIVALENCE (NTEGER39, NTF111), (NTEGER40, NTF111), (NTEGER41, NTF111).  DEIN 20
      EQUIVALENCE (NTEGER42, NTF111), (NTEGER43, NTF111), (NTEGER44, NTF111).  DEIN 21
      EQUIVALENCE (NTEGER45, NTF111), (NTEGER46, NTF111), (NTEGER47, NTF111).  DEIN 22
      EQUIVALENCE (NTEGER48, NTF111), (NTEGER49, NTF111), (NTEGER50, NTF111).  DEIN 23
      EQUIVALENCE (NTEGER51, NTF111), (NTEGER52, NTF111), (NTEGER53, NTF111).  DEIN 24
      EQUIVALENCE (NTEGER54, NTF111), (NTEGER55, NTF111), (NTEGER56, NTF111).  DEIN 25
      EQUIVALENCE (NTEGER57, NTF111), (NTEGER58, NTF111), (NTEGER59, NTF111).  DEIN 26
      EQUIVALENCE (NTEGER60, NTF111), (NTEGER61, NTF111), (NTEGER62, NTF111).  DEIN 27
      EQUIVALENCE (NTEGER63, NTF111), (NTEGER64, NTF111), (NTEGER65, NTF111).  DEIN 28
      INPUT DATA
      NTEGEN11 = IDENT - PROBLEM NUMBER      DEIN 29
      NTEGER12 = NPF1 - THE NUMBER OF SLTS OF DATA TO BE READ IN      DEIN 29
      BY FORMAT 1      DEIN 29
      NTEGEN13 = NPF2 - THE NUMBER OF PARAMETERS TO BE READ IN      DEIN 29
      BY FORMAT 2      DEIN 29
      NTEGEN14 = NPF3 - THE NUMBER OF SETS OF INTEGERS TO RF      DEIN 29
      READ IN BY FORMAT 3      DEIN 29
      NTEGEN15 = NPF4 - NUMBER OF SETS OF INTEGERS TO BE READ IN      DEIN 29
      BY FORMAT 4      DEIN 29
      NTEGEN16 = NPF5 - THE NUMBER OF QUADRUPLE TABLES TO BE READ INDE      DEIN 29
      NTEGER17 = NTF1 - 1 FOR QUADRUPLE TABLE PRINT, 0 OTHERWISE      DEIN 29
      NTEGER18 = MONTH      DEIN 29
      NTEGER19 = DAY      DEIN 29
      NTEGER10 = NPSIL - THE NUMBER OF INTERNAL LOAD LEVELS USED      DEIN 29
      FOR INTEGRATION OF JOINT DENSITY FUNCTION      DEIN 29
      INTERNAL LOAD SPECTRUM      DEIN 29
      NTEGER11 = NPSIL - THE NUMBER OF LOAD LEVELS IN THE      DEIN 29
      INTERNAL LOAD SPECTRUM      DEIN 29
      NTEGEN16 = NPS - THE NUMBER OF CONTROL POINTS      DEIN 29
      NTEGER14 = NMORE - NUMBER OF ADDITIONAL INTEGERS PLUS 14      DEIN 29
      NTEGER15 = NRW1 - INDICATED AIRSPEED INTERVAL SUBDIVISION      DEIN 29
      NTEGEN16 = NPNZ - LOAD FACTOR INTERNAL SUBDIVISIONS      DEIN 29
      NTEGER17 = MRH - ALTITUDE INTERNAL SURVEYCTIONS      DEIN 29
      NTEGEN18 = NWK - WEIGHT INTERNAL SURVEYCTIONS      DEIN 29
      NTEGEN19 = NIB - 1 FOR QUADRUPLE TABLE LOOK UP CASE      DEIN 29
      NTEGEN20 = 2 FOR TRIPLE TABLE LOOK UP CASE      DEIN 29
      P(1) - FV1 - LEAST UPPER BOUND OF V1 IN HISTOGRAM      DEIN 29
      P(2) - FN2 - LEAST UPPER BOUND OF V2 IN HISTOGRAM      DEIN 29
      P(3) - FM - LEAST UPPER BOUND OF M IN HISTOGRAM      DEIN 29
      P(4) - FW - LEAST UPPER BOUND OF W IN HISTOGRAM      DEIN 29
      P(5) - FACTOR - LOAD MAGNIFICATION FACTOR      DEIN 29
      P(6) - HOURS - NUMBER OF HOURS OF DATA IN HISTOGRAM      DEIN 29
      P(10) - PSIL111 - FIRST LOAD LEVEL FOR PROBABILITY CALC.      DEIN 29
      P(20) - AREAN11 - FIRST OPO. OF CUM. PROC. FUNC. FOR SPEC. -      DEIN 29
      IF (NPS) 10, 10, 2      DEIN 29
      NPAGF = NFLAG + 1      DEIN 29
      GO TO 3C      DEIN 29
      NPAUF = 1      DEIN 29
      READ INTEGERS INC THE PRGLEM      DEIN 29
      11      DEIN 29
      C

```

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SUBROUTINE INPUT

MAIN -OPT=1

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```
      115          READ (5,140) (TANL4(K,I), K = 1, NTT4)
      READ (5,140) (TANL6(K,I), K = NTT1P1, NNTT12)
      READ (5,140) (TANL6(K,I), K = NTT1P1,
      GO TO (654,656), J
      GO TO (656,660), K10
      READ (5,140) (TANL4(K,I), K = NNT13P1, NNTT14)
      READ (5,140) (TANL4(K,I), K = NNT13P1,
      GO TO 670
      READ (5,140) MTB3
      NF = NNT13 + NTP
      READ (5,140) (TANL6(K,I), K = NN13P1, NF)
      CONTINUE
      CALL INIC
      RETURN
      END
```

125

115

654

656

660

662

K10

J

I

DEFIN104

DEFIN105

DEFIN106

DEFIN107

DEFIN108

DEFIN109

DEFIN110

DEFIN111

```

----- SUBROUTINE JNAO ----- 76476 - OPT21 ----- FIN A-80753 ----- 31/02/73 - 00:05:22. ----- PAGE ----- 4

C   SUBROUTINE FOR WRITING OUT INPUT DATA
COMMON P100001, MTFGRN01, TABL422000,21,
      TABL215000,11
      DIMENSION PSIL(100), AREAN1001, PS125,-251
      DIMENSION NTR01(42), NTR02(21), NTR03(21), NTR04(47)
      EQUIVALENCE (P101), FM1, (P151), FACT01
      EQUIVALENCE (P111), FM1, (P121), FM2, -(P131), -FM1
      EQUIVALENCE (P199), NTR05
      EQUIVALENCE (P1001), FSLL1, (P1201), AREAN01
      EQUIVALENCE (P1301), PS1
      EQUIVALENCE (P1012), NTR06, (P1111), NPS11, (P1211), NPS12
      EQUIVALENCE (P1013), NTR07, (P1112), NPS13, (P1212), NPS14
      EQUIVALENCE (P1014), NTR08, (P1113), NPS15, (P1213), NPS16
      EQUIVALENCE (P1015), NTR09, (P1114), NPS17, (P1214), NPS18
      EQUIVALENCE (P1016), NTR010, (P1115), NPS19, (P1215), NPS20
      EQUIVALENCE (P1017), NTR011, (P1116), NPS21, (P1216), NPS22
      EQUIVALENCE (P1018), NTR012, (P1117), NPS23, (P1217), NPS24
      EQUIVALENCE (P1019), NTR013, (P1118), NPS25, (P1218), NPS26
      EQUIVALENCE (P101A), NTR014, (P1119), NPS27, (P1219), NPS28
      EQUIVALENCE (P101B), NTR015, (P111A), NPS29, (P121A), NPS30
      EQUIVALENCE (P101C), NTR016, (P111B), NPS31, (P121B), NPS32
      EQUIVALENCE (P101D), NTR017, (P111C), NPS33, (P121C), NPS34
      EQUIVALENCE (P101E), NTR018, (P111D), NPS35, (P121D), NPS36
      EQUIVALENCE (P101F), NTR019, (P111E), NPS37, (P121E), NPS38
      EQUIVALENCE (P101G), NTR020, (P111F), NPS39, (P121F), NPS40
      EQUIVALENCE (P101H), NTR021, (P111G), NPS41, (P121G), NPS42
      EQUIVALENCE (P101I), NTR022, (P111H), NPS43, (P121H), NPS44
      EQUIVALENCE (P101J), NTR023, (P111I), NPS45, (P121I), NPS46
      EQUIVALENCE (P101K), NTR024, (P111J), NPS47, (P121J), NPS48
      EQUIVALENCE (P101L), NTR025, (P111K), NPS49, (P121K), NPS50
      EQUIVALENCE (P101M), NTR026, (P111L), NPS51, (P121L), NPS52
      EQUIVALENCE (P101N), NTR027, (P111M), NPS53, (P121M), NPS54
      EQUIVALENCE (P101O), NTR028, (P111N), NPS55, (P121N), NPS56
      EQUIVALENCE (P101P), NTR029, (P111O), NPS57, (P121O), NPS58
      EQUIVALENCE (P101Q), NTR030, (P111P), NPS59, (P121P), NPS60
      EQUIVALENCE (P101R), NTR031, (P111Q), NPS61, (P121Q), NPS62
      EQUIVALENCE (P101S), NTR032, (P111R), NPS63, (P121R), NPS64
      EQUIVALENCE (P101T), NTR033, (P111S), NPS65, (P121S), NPS66
      EQUIVALENCE (P101U), NTR034, (P111T), NPS67, (P121T), NPS68
      EQUIVALENCE (P101V), NTR035, (P111U), NPS69, (P121U), NPS70
      EQUIVALENCE (P101W), NTR036, (P111V), NPS71, (P121V), NPS72
      EQUIVALENCE (P101X), NTR037, (P111W), NPS73, (P121W), NPS74
      EQUIVALENCE (P101Y), NTR038, (P111X), NPS75, (P121X), NPS76
      EQUIVALENCE (P101Z), NTR039, (P111Y), NPS77, (P121Y), NPS78
      EQUIVALENCE (P101A1), NTR040, (P111Z), NPS79, (P121Z), NPS80
      EQUIVALENCE (P101B1), NTR041, (P111A1), NPS81, (P121A1), NPS82
      EQUIVALENCE (P101C1), NTR042, (P111B1), NPS83, (P121B1), NPS84
      EQUIVALENCE (P101D1), NTR043, (P111C1), NPS85, (P121C1), NPS86
      EQUIVALENCE (P101E1), NTR044, (P111D1), NPS87, (P121D1), NPS88
      EQUIVALENCE (P101F1), NTR045, (P111E1), NPS89, (P121E1), NPS90
      EQUIVALENCE (P101G1), NTR046, (P111F1), NPS91, (P121F1), NPS92
      EQUIVALENCE (P101H1), NTR047, (P111G1), NPS93, (P121G1), NPS94
      EQUIVALENCE (P101I1), NTR048, (P111H1), NPS95, (P121H1), NPS96
      EQUIVALENCE (P101J1), NTR049, (P111I1), NPS97, (P121I1), NPS98
      EQUIVALENCE (P101K1), NTR050, (P111J1), NPS99, (P121J1), NPS100
      EQUIVALENCE (P101L1), NTR051, (P111K1), NPS101, (P121K1), NPS102
      EQUIVALENCE (P101M1), NTR052, (P111L1), NPS103, (P121L1), NPS104
      EQUIVALENCE (P101N1), NTR053, (P111M1), NPS105, (P121M1), NPS106
      EQUIVALENCE (P101O1), NTR054, (P111N1), NPS107, (P121N1), NPS108
      EQUIVALENCE (P101P1), NTR055, (P111O1), NPS109, (P121O1), NPS110
      EQUIVALENCE (P101Q1), NTR056, (P111P1), NPS111, (P121P1), NPS112
      EQUIVALENCE (P101R1), NTR057, (P111Q1), NPS113, (P121Q1), NPS114
      EQUIVALENCE (P101S1), NTR058, (P111R1), NPS115, (P121R1), NPS116
      EQUIVALENCE (P101T1), NTR059, (P111S1), NPS117, (P121S1), NPS118
      EQUIVALENCE (P101U1), NTR060, (P111T1), NPS119, (P121T1), NPS120
      EQUIVALENCE (P101V1), NTR061, (P111U1), NPS121, (P121U1), NPS122
      EQUIVALENCE (P101W1), NTR062, (P111V1), NPS123, (P121V1), NPS124
      EQUIVALENCE (P101X1), NTR063, (P111W1), NPS125, (P121W1), NPS126
      EQUIVALENCE (P101Y1), NTR064, (P111X1), NPS127, (P121X1), NPS128
      EQUIVALENCE (P101Z1), NTR065, (P111Y1), NPS129, (P121Y1), NPS130
      EQUIVALENCE (P101A2), NTR066, (P111Z1), NPS131, (P121Z1), NPS132
      EQUIVALENCE (P101B2), NTR067, (P111A2), NPS133, (P121A2), NPS134
      EQUIVALENCE (P101C2), NTR068, (P111B2), NPS135, (P121B2), NPS136
      EQUIVALENCE (P101D2), NTR069, (P111C2), NPS137, (P121C2), NPS138
      EQUIVALENCE (P101E2), NTR070, (P111D2), NPS139, (P121D2), NPS140
      EQUIVALENCE (P101F2), NTR071, (P111E2), NPS141, (P121E2), NPS142
      EQUIVALENCE (P101G2), NTR072, (P111F2), NPS143, (P121F2), NPS144
      EQUIVALENCE (P101H2), NTR073, (P111G2), NPS145, (P121G2), NPS146
      EQUIVALENCE (P101I2), NTR074, (P111H2), NPS147, (P121H2), NPS148
      EQUIVALENCE (P101J2), NTR075, (P111I2), NPS149, (P121I2), NPS150
      EQUIVALENCE (P101K2), NTR076, (P111J2), NPS151, (P121J2), NPS152
      EQUIVALENCE (P101L2), NTR077, (P111K2), NPS153, (P121K2), NPS154
      EQUIVALENCE (P101M2), NTR078, (P111L2), NPS155, (P121L2), NPS156
      EQUIVALENCE (P101N2), NTR079, (P111M2), NPS157, (P121M2), NPS158
      EQUIVALENCE (P101O2), NTR080, (P111N2), NPS159, (P121N2), NPS160
      EQUIVALENCE (P101P2), NTR081, (P111O2), NPS161, (P121O2), NPS162
      EQUIVALENCE (P101Q2), NTR082, (P111P2), NPS163, (P121P2), NPS164
      EQUIVALENCE (P101R2), NTR083, (P111Q2), NPS165, (P121Q2), NPS166
      EQUIVALENCE (P101S2), NTR084, (P111R2), NPS167, (P121R2), NPS168
      EQUIVALENCE (P101T2), NTR085, (P111S2), NPS169, (P121S2), NPS170
      EQUIVALENCE (P101U2), NTR086, (P111T2), NPS171, (P121T2), NPS172
      EQUIVALENCE (P101V2), NTR087, (P111U2), NPS173, (P121U2), NPS174
      EQUIVALENCE (P101W2), NTR088, (P111V2), NPS175, (P121V2), NPS176
      EQUIVALENCE (P101X2), NTR089, (P111W2), NPS177, (P121W2), NPS178
      EQUIVALENCE (P101Y2), NTR090, (P111X2), NPS179, (P121X2), NPS180
      EQUIVALENCE (P101Z2), NTR091, (P111Y2), NPS181, (P121Y2), NPS182
      EQUIVALENCE (P101A3), NTR092, (P111Z2), NPS183, (P121Z2), NPS184
      EQUIVALENCE (P101B3), NTR093, (P111A3), NPS185, (P121A3), NPS186
      EQUIVALENCE (P101C3), NTR094, (P111B3), NPS187, (P121B3), NPS188
      EQUIVALENCE (P101D3), NTR095, (P111C3), NPS189, (P121C3), NPS190
      EQUIVALENCE (P101E3), NTR096, (P111D3), NPS191, (P121D3), NPS192
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      NIT624 = NITIA624(1,1)
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SUBROUTINE: MAIN : 74376 , DPT=1
FIN 4.8.8361 ----- 11/92/71 - 09.05.22. - PAGE - 3

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      TON, 0.0PNZ • E15.6 /   INAO 67
      10, 0PNH = 0 E15.6 /   INAO 68
      10, 0PNW = 0 E15.6 /   INAO 69
      NZERO = 1               INAO 90
      RETURN
      END
      120
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145      6C      WRITE(10X, 26HGAUSS2) ERROR SIGNAL + K3 N + 131
146      70      FORMAT(10X, 26HGAUSS2)
147      80      IF (11-11, 140, 100, 90
148      81      IF (11-NPLM2), 120, 110, 148
149      90      PPSI1(1) = 2.0 * X(11) * PSIL(11) * X(12)
150      100
151      110      PPSI1(2) = 2.0 * X(11) * PSIL(12) * X(2)
152      120      PPSI1(1) = 2.0 * X(11) * PSIL(11) * X(12)
153      130      RETURN
154      140
155      150
156      160
157      170
158      180
159      190
160      200
161      210
162      220
163      230
164      240
165      250
166      260
167      270
168      280
169      290
170      300
171      310
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173      330
174      340
175      350
176      360
177      370
178      380
179      390
180      400
181      410
182      420
183      430
184      440
185      450
186      460
187      470
188      480
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190      500
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199      590
200      600
201      610
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207      670
208      680
209      690
210      700
211      710
212      720
213      730
214      740
215      750
216      760
217      770
218      780
219      790
220      800
221      810
222      820
223      830
224      840
225      850
226      860
227      870
228      880
229      890
230      900
231      910
232      920
233      930
234      940
235      950
236      960
237      970
238      980
239      990
240      1000
241      1010
242      1020
243      1030
244      1040
245      1050
246      1060
247      1070
248      1080
249      1090
250      1100
251      1110
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      3          A GIVEN HISTORY OF LOAD CYCLES
      4          COMMON P1188881, NFEGR1001, JARL4(2888), 21
      5          DIMENSION PSIL1(100), APOTS1(100)
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SUBROUTINE LDVLN 7474 DPIT=1

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1 AREANINPSILL-III / 2.0

RETURN

END

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LDLV 458

LDLV 46

LDLV 47

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C   SUBROUTINE LDCOFF
      SUBROUTINE FOR COMPUTING THE LOAD CONDUCTION COEFFICIENTS
      COMMON P1(0:1000), W1CER(1000), TAU(1000:21),
      1  TA(0:21500,10)
      DIMENSION PS1(1000), PS125(25), ALPHA(25),
      1  PL0(100,25), ALP5(5,25), AINV(25,25), PL0(25),
      1  EQUIVALENCE (PL0(100,1),PS1), (PL0(30,1),PS11),
      1  (PL0(15,1),PS12), (ALP5(1,1),ALPHAI),
      1  (ALP5(1,5),ALPHAI5), (ALP5(5,1),ALPHAI5),
      1  EQUIVALENCE (INTEGR121, NPS111), (INTEGR131, NPS1),
      1  (INTGR1631, NPAF1), (INTGR1531, NPS11),
      1  (NPS11, NPS111), (NPS111, NPS1),
      DC 10  I = 1, NPS11
      PL0(1,1:NPS1) = PS11(1:I)
      IF (NPS1 < 130) 130, 20, 20
      DO 50 I = 1, NPS1
      DO 50 J = 1, NPS1
      AI(J,I) = S1(I,J)
      JNPS = J * NPS1
      IF (I .LT. J) 40, 30, 40
      AI(I,JNPS) = 1.0
      GO TO 50
      AI(JNPS) = 0.0
      CONTINUE
      CALL GAUS21(NPS1, NPS1, 1.0E-07, A, AJN, K31)
      IF (K3 .LT. -1) 60, 75, 60
      MAT(16,70) K3
      FORMAT (10X, 24HGAUS21 ERROR SIGNAL - K3 = , I5 )
      NPAF = NPAF + 1
      CALL PAC1D
      DO 120 J = 1, NPS1
      DO 80 J = 1, NPS1
      PL0(J,I) = FLIS(1,J)
      DO 90 K = 1, NPS1
      ALPHAI(K) = 0.0
      OC = 90, L = 1, NPS1
      ALPHAI(L) = AINV(L,I) * PL0(L) + ALPHA(L)
      WRITE (6,100) 1
      FORMAT (1/10Y, 36H COEFFICIENTS FOR FREQUENCY LEVEL NO. , I5 )
      100  FORMAT (1/10Y, 36H COEFFICIENTS FOR FREQUENCY LEVEL NO. , I5 )
      110  FORMAT (1/10Y, 36H COEFFICIENTS FOR FREQUENCY LEVEL NO. , I5 )
      120  CONTINUE
      130  RETURN
      END

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SUBROUTINE XFACT

TWTs - OPT1

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      1   AMP, NTAB1, NTAB2, XTAB1
      C   SUBROUTINE XFACT, X1ARG, X2ARG, X3ARG
      C   SUBROUTINE FOR STRAIGHT LINE INTERPOLATION IN A TRIPLE
      C   TABLE LOOK UP
      DIMENSION TABLE(2000)
      DO 10 I1 = 1, NTAB1
      IF (TABLE(I1) - X1ARG) 10, 20, 20
      CONTINUEF
      I1 = NTAB1
      IF (I1 - 1) 30, 30, 40
      I1 = 2
      NT1P1 = NTAB1 + 1
      MN12 = NTAB1 + NTAB2
      DO 40 I2 = 1, NTAB2
      IF (TABLE(I1) - X2ARG) 10, 20, 20
      CONTINUEF
      I2 = NTAB2
      IF (I2 - 1) 30, 30, 40
      I2 = 2
      NT2P1 = NTAB2 + 1
      MN13 = NTAB1 + NTAB3
      DO 50 I3 = 1, NTAB3
      IF (TABLE(I1) - X3ARG) 10, 20, 20
      CONTINUEF
      I3 = NTAB3
      IF (I3 - 1) 30, 30, 40
      I3 = 2
      NT3P1 = NTAB3 + 1
      MN14 = NTAB1 + NTAB2 + NTAB3
      DO 60 I4 = 1, MN14
      IF (TABLE(I1) - X1ARG) 90, 100, 100
      CONTINUEF
      I4 = MN14
      J1 = 113 - I1*P1
      J1 = 110, 110, 120
      N112 = MN12 + 2
      NP12 = MN12 + 1
      N113 = MN13 + 2
      NP13 = MN13 + 1
      N114 = MN14 + 2
      NP14 = MN14 + 1
      N112 = N222 - 1
      N113 = N223 - 1
      N114 = N224 - 1
      N222 = N222 + NP12
      N223 = N223 + NP13
      N224 = N224 + NP14
      N112 = N222 - 1
      N113 = N223 - 1
      N114 = N224 - 1
      N222 = N222 + NP12
      N223 = N223 + NP13
      N224 = N224 + NP14
      N112 = N222 - 1
      N113 = N223 - 1
      N114 = N224 - 1
      X1P1 = X1ARG - TABLE(I1)-11)
      X2P1 = X2ARG - TABLE(I1)-11)
      X3P1 = X3ARG - TABLE(I1)-11)
      X1RAT = TABLE(I12)-10)
      X2RAT = TABLE(I12)-10)
      X3RAT = TABLE(I12)-10)
      AMP11 = TABLE(I11) + X1P1 * (TABLE(I12)-11)
      AMP12 = TABLE(I11) + X2P1 * (TABLE(I12)-11)
      AMP13 = TABLE(I11) + X3P1 * (TABLE(I12)-11)
      AMP21 = TABLE(I12) + X1P1 * (TABLE(I12)-11)
      AMP22 = TABLE(I12) + X2P1 * (TABLE(I12)-11)
      AMP23 = TABLE(I12) + X3P1 * (TABLE(I12)-11)
      AMP12 = TABLE(I12) + X1P1 * (TABLE(I12)-11)
      AMP22 = TABLE(I12) + X2P1 * (TABLE(I12)-11)
      AMP33 = TABLE(I12) + X3P1 * (TABLE(I12)-11)
      AMP11 = AMP11 + X1P1 * (AMP21 - AMP11)
      AMP12 = AMP12 + X2P1 * (AMP22 - AMP12)
      AMP13 = AMP13 + X3P1 * (AMP23 - AMP13)
      RETURN
      END

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— 11111111111111111111111111111111 — PAGE 1 —

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      1 TABLE(112) = TABLE(112-11)
      1 X3DAT = X3DAT - TABLE(113-11) /          QTAB 58
      1 TABLE(113) = TABLE(113-11)               QTAB 59
      1 X4DAT = X4DAT - TABLE(114-11)               CTAB 60
      1 (TABLE(111) - TABLE(111-11)) * KIRAT * (TABLE(11211) - QTAB 61
      1 TABLE(111) * TABLE(111-11) * KIRAT * (TABLE(11211) - QTAB 62
      1 TABLE(11111) * KIRAT * (TABLE(11211) - QTAB 63
      1 TABLE(11111) * KIRAT * (TABLE(11211) - QTAB 64
      1 TABLE(11111) * KIRAT * (TABLE(11211) - QTAB 65
      1 TABLE(11111) * KIRAT * (TABLE(11211) - QTAB 66
      1 TABLE(11111) * KIRAT * (TABLE(11211) - QTAB 67
      1 TABLE(11111) * KIRAT * (TABLE(11211) - QTAB 68
      1 TABLE(11111) * KIRAT * (TABLE(11211) - QTAB 69
      1 TABLE(11111) * KIRAT * (TABLE(11211) - QTAB 70
      1 TABLE(11112) = TABLE(11112) + KIRAT * (TABLE(11212) - QTAB 71
      1 TABLE(11112) = TABLE(11112) + KIRAT * (TABLE(11212) - QTAB 72
      1 TABLE(11112) = TABLE(11112) + KIRAT * (TABLE(11212) - QTAB 73
      1 TABLE(11112) = TABLE(11112) + KIRAT * (TABLE(11212) - QTAB 74
      1 TABLE(11112) = TABLE(11112) + KIRAT * (TABLE(11212) - QTAB 75
      1 TABLE(11112) = TABLE(11112) + KIRAT * (TABLE(11212) - QTAB 76
      1 TABLE(11112) = TABLE(11112) + KIRAT * (TABLE(11212) - QTAB 77
      1 TABLE(11112) = TABLE(11112) + KIRAT * (TABLE(11212) - QTAB 78
      1 TABLE(11112) = AMP111 + X2RAT * JAMP211 * AMF1111 - QTAB 79
      1 AMP111 = AMP111 + X2RAT * (AMP221 - AMP121) - QTAB 80
      1 AMP112 = AMP112 + X2RAT * (AMP212 - AMP121) - QTAB 81
      1 AMP112 = AMP112 + X2RAT * (AMP222 - AMP122) - CTAB 82
      1 AMP1 = AMP111 + X2RAT * (AMF211 - AMP111) - QTAB 83
      1 AMP2 = AMP112 + X2RAT * (AMF212 - AMP121) - QTAB 84
      1 AMP2 = AMP112 + X2RAT * (AMP22 - AMP121) - QTAB 85
      1 AMP = AMP1 + XLSAT * (AMP2 - AMP1) - QTAB 86
      RETURN
      ENO
      QTAB 87

```

SUBROUTINE PAGEID

JAN74

— OPT14 — FIN.4.062153 — 11/02/23 09:05:51. — PAGE 1

```
C      SUBROUTINE PAGEID  PAGH 1
      COMMON P100001, M1GEN1001, TANL47000.20,          PAGH 2
      TABLE250001
      5      INTEGER DAY, YFAD, IDENT1, IDENT2, MONTH1,      PAGH 3
              EQUIVALENCE IDENT1, IDENT2, MONTH1,          PAGH 4
              IDENT1, IDENT2, YEAR1, IDENT2, M1GEN1001,      PAGH 5
              WRITE(16,201) IDENT1, MONTH, DAY, YFAD, NPAGE      PAGH 6
              20      FORMAT(1X,0X,6HRUN NO., 16, 10X, 4HDATE, 14, 1W, 12,      PAGH 7
              10      10X, 7PAGE NO., 16)      PAGH 8
              14      RETURN      PAGH 9
              END      PAGH 10
              .      PAGH 11
              .      PAGH 12
              .      PAGH 13
              .      PAGH 14
```

SUBROUTINE GAUSS2 — 762a

OPTION — FINA-0-253 — 11/22/73 — 89-05-5a — PAGE — 1 —

GAUSS2(M,EP,A,X,K,N)

DIMENSION A(3,4), X(3,1)

NPM=4*M

L=1,N

KP=0

R=0.0

DO 1,2 K=L,N

16 17 ANS=(A(K,L))11,12,12

18 DO 1,2 K=L,N

19 20 KPA=

21 CONTINUE

22 R=(L-KP)13*20,20

23 DO 1,4 J=L,NPM

24 Z=A(L,J)

25 A(L,J)=A(KP,J)

26 A(K,J)=2

27 T=(L-S)11,12,-EP150,50,30

28 IF (L-S)31,40,40

29 LPI=L+1

30 DO 34 K=LPI,N

31 T=(L-K,LP1,L)

32 IF (L-K,L)32,36,32

33 Q=(L-K,L)31,NPM

34 A(K,J)=A(K,J)-PAT01(L,J)

35 CONTINUE

36 DO 43 I=1,N

37 IF (I=1,1)

38 P=N

39 S=0.1

40 IF (I=1-N)41,43,43

41 LP1=L+1

42 DO 42 K=LP1,N

43 S=(A(I,J)-A(K,J))

X(I,J)=A(I,J)-PN-S1/(A(I,J))

44 K=R-1

45 GO TO 75

46 N=R-2

47 CONTINUE

48 RETURN

49 ENO

GAUS 001

GAUS 002

GAUS 003

GAUS 004

GAUS 005

GAUS 006

GAUS 007

GAUS 008

GAUS 009

GAUS 010

GAUS 011

GAUS 012

GAUS 013

GAUS 014

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GAUS 016

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GAUS 032

GAUS 033

GAUS 034

GAUS 035

GAUS 036

GAUS 038

GAUS 039

GAUS 040

SUBROUTINE GAUS21 — 2676 — OPT1 — FIN 4-JAP1911 — 11/22/73 09:05:01. — PAGE — 1 —

```
      SUBROUTINE GAUS21(M,N,EP,AV,KERB)
      DIMENSION A(125,20), X(125,25)
      NEM144M
      M=1
      N=34 L=1,N
      MP=0
      Z=0,0
      10 12 KAL,M
      IF (Z>ANS) GOTO 11,12,13
      11 2=185 (A(L,K,L))
      12 K=P=X
      13 CONTINUE
      IF (L-KP1) 3,20,20
      14 16 J=L,NPM
      15 17 A(L,J)=A(L,P,J)
      16 A(L,P)=2
      17 E145*(A(L,L))-EP150+50,30
      18 19 IF (L-K) 31,40,40
      20 21 EP150+50,30
      22 23 IF (L-K) 31,40,40
      24 25 EP150+50,30
      26 27 00 34 K=L,P1,N
      28 29 IF (A(L,N),L13)>36,32
      30 31 R110=A(L,N)/A(L,L)
      32 33 DC 33 J=L,P1,NPM
      34 35 A(L,J)=A(L,J)-RATIO*A(L,J)
      36 37 C=0,T1,N
      38 39 II=N+1,I
      40 41 II=I+1,N
      42 43 JP1=0+N
      44 45 S=0,0
      46 47 TIP1=II+1,M3+3
      48 49 II+1-M3+3
      50 51 TIP1=II+1,N
      52 53 DO 42 K=1,TIP1,N
      54 55 S=C,A(II,K),X(K,J)
      56 57 X(II,J)=A(II,J)-JP1-S/A(II,II)
      58 59 K=K+1
      60 61 CG 19 75
      62 63 KERB=2
      64 65 C=M1NUF
      66 67 RETURN
      68 69 END
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      1112 1113
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SHARQUSINE PRINTER

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OPT1

FIN. A.43213

PAGE 2

```
MPAGE 8. MPAGE 3.  
CALL PAGE0  
60 WRITE 16,00  
WHITE 16,00  
FORMAT1/101. 2MHCYCLIC LOADING, FRACTIONS.)  
WRITE (6,70)  
70 FORMATS (15P, UNLOAD, 5X, UNLOAD, 5X,  
ANFAC10CK, 19X, ANLOAD, 5X, UNFAC10CK)  
DO 80 I = 1, MPSILL, 3  
11 = 1, 1  
12 = 1, 2  
WRITE (46,30) MPSILL1, MPSILL2, MPSILL3,  
80 MPSILL123, HYAC121  
I MPSILL (6,50) NT  
70 FORMAT1/101, 19-INITIAL LOAD CYCLES =, F12.00  
RETURN  
END  
PONI 61
```